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GEOLOGY AND MINERAL DEPOSITS OF ESMERALDA COUNTY, NEVADA

(Prepared cooperatively by the United States Geological Survey)

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FOREWORD

For a number of years the U. S. Geological Survey and the Nevada Bureau of Mines and Geology have worked together in a cooperative program to provide information on Nevada's geology and mineral resources. The current report on Esmeralda County is the latest in this series of county-by-county studies.

Esmeralda County was one of the original nine counties of Nevada Territory. Few political areas in the State have been more affected by the vicissitudes of mining history and the accident of geographical location. Twice halved to form new counties, Esmeralda's size and shape were variously altered by population changes as new mining districts were formed and by relocation of the boundary between Nevada and California.

Settled by prospectors and miners, Esmeralda County has survived almost entirely by mining throughout its history. In addition to the rich production of precious metals from Goldfield, the county has produced commercially ten other metals and twelve industrial minerals. According to the authors, Esmeralda had produced between \$122 and \$123 million through 1965, most of which was recorded during the peak Goldfield years between 1904 and 1915. It is interesting to note, however, that between 1966 and 1970, an additional \$12 to \$13 million have been added to the total — with values primarily in minerals other than the gold and silver of the County's early boom days. One of the world's principal sources of lithium is Clayton Valley in the central part of the County, where since 1965 the light metal has been produced from brines pumped from the valley fill. Other minerals have contributed to the total production, and still more have been proven which will have commercial value in the future. The present report will assist substantially in the successful development of these resources.

Bulletin 78, "The Geology and Mineral Deposits of Esmeralda County, Nevada," by J. P. Albers and J. H. Stewart of the U. S. Geological Survey, is based on field work begun in 1960 and completed in 1962. Economic information was added through 1965. Since that period, continued exploration and mining activity in the County confirm its variety of mineral deposits and economic potential for the future.

Arthur Baker III, *Acting Director*
Nevada Bureau of Mines and Geology

January, 1973
Mackay School of Mines
University of Nevada

GEOLOGY AND MINERAL DEPOSITS OF ESMERALDA COUNTY, NEVADA[1]

By JOHN P. ALBERS and JOHN H. STEWART

ABSTRACT

Esmeralda County covers about 3,570 square miles in the southwestern part of Nevada adjacent to the California border. The topography is dominated by arcuate ranges having southward convexity and by intervening valleys. The lowest point in the county is about 3,700 feet; the highest in the county, as well as in the State of Nevada, is 13,145 feet.

The rocks exposed consist of sedimentary, igneous, and metamorphic types ranging in age from late Precambrian to Holocene. Upper Precambrian and Lower Cambrian strata are widely exposed in the southern two-thirds of the county and consist of over 12,000 feet of siltstone, shale, very fine-grained to fine-grained quartzite, and minor amounts of limestone and dolomite. Metamorphic equivalents of these rocks occur near granitic intrusives. These strata are assigned to seven formations. Middle and Upper Cambrian strata are several thousand feet thick and consist predominantly of thin-bedded limestone and chert, and, in the southernmost part of the county, of dolomite and limestone. Ordovician strata in most of the county consist of shale and siltstone and minor amounts of limestone, chert, and quartzite. In the southernmost part of the county, Ordovician strata are mostly limestone. No Silurian nor Devonian strata are known. Mississippian strata crop out only in an area of less than a square mile in the southernmost part of the county and consist mostly of shale. No strata of Pennsylvanian Age are known. Permian strata, consisting of sandstone, conglomerate, and dolomite, crop out in a small area in the northern part of the county.

Triassic, Triassic(?), and Jurassic rocks crop out only in the northern third of the county and apparently occur in two structural plates. The lower plate consists dominantly of shale, sandstone, and limestone, and the upper plate consists of a thick sequence of greenstone and greenstone breccia overlain by conglomerate, sandstone, shale, and limestone.

Coarse-grained plutonic rocks, which are at least in part of Jurassic and younger age, based on radiometric K-A dating, crop out in 30 separate bodies ranging in size from a few acres to about 400 square miles. Most of these bodies have the composition of quartz monzonite.

Tertiary rocks are extensively exposed in the county and include welded and nonwelded ash flows, lava flows, volcanic breccia, and fresh-water sedimentary rocks. The volcanic rocks range in composition from rhyolitic to basaltic; those having the composition of quartz latite are the most common. The thickness and lithologic character of the Tertiary section differ greatly from one range to another within the county. The maximum thickness is in the Silver Peak Mountains where a pile of sedimentary and volcanic rocks several thousand feet thick is exposed. The earliest period of volcanic activity in the county probably took place in the vicinity of Goldfield about 25 to 26 million years ago. Other periods of volcanic activity occurred about 21 to 22 and 4 to 7 million years ago. The oldest sedimentary deposits are probably about 17 million years old, and the bulk of the sedimentary deposits probably formed 10 to 13 million years ago.

Esmeralda County lies within a zone of disrupted structure at least 300 miles long and 50 to 100 miles wide that forms a transition between the northwest-trending Sierra Nevada block to the west and the north-northeast-trending ranges of the Great Basin province to the east. Within the county, major structures have an arcuate shape, convex to the south, suggesting a great amount of drag due to right-lateral shear. Strike-slip faults with displacements of many miles occur in the westernmost and northern parts of the county. Many high-angle faults with dip-slip movement cut the arcuate structures.

Low-angle faults or thrusts, having dips less than 45° and mostly less than 20°, are extremely common in the pre-Tertiary rocks of Esmeralda County, but they do not affect the Tertiary. At least 50 percent of the contacts between pre-Tertiary rock units, excluding igneous rocks, are thrusts. In addition, many thrusts occur within formations. At least 75 percent of the thrusts have younger rocks in the upper plate, but some of the most extensive thrusts show older rocks on top of younger.

Mining has been the only significant industry of Esmeralda County since the first mineral discoveries in the 1850's. The first recorded production was in 1867, and through 1965 the total value of minerals produced was about $123 million. Although gold has been by far the most important product, Esmeralda County has also yielded at least 22 other mineral substances in commercial amounts, and in addition contains occurrences of still other minerals, some of which may eventually be of commercial value.

Metallic minerals that have been produced commercially are antimony, copper, gold, iron, lead, lithium, mercury, molybdenum, silver, tungsten, and zinc. More than 75 percent of the recorded mineral production of Esmeralda County has come from the gold-producing Goldfield district. At least 98 percent of the production from this district was from a belt less than a mile long and a few hundred feet wide in Tertiary volcanic rocks.

Nonmetallic and industrial mineral deposits that have been produced commercially are: alum and sulfur, barite, borates, clays, coal, diatomite, dimension stone, gems and gem materials, perlite, sand and gravel, silica, and talc and soapstone.

[1]Publication authorized by the Director, U.S. Geological Survey.

INTRODUCTION

Esmeralda County, one of the original nine counties of Nevada "Territory," was formed in 1861 and took its name from the Esmeralda (Aurora) mining district. "Esmeralda" is the Spanish name for emerald, and it is of interest that it was a close rival of "Nevada" when a name was being selected for the State. As originally delineated, Esmeralda County included most of what is now Nye County and all of Mineral County. Its size and shape were altered several times over the years with changes in population, with discovery of new mining districts, and with the relocation of the boundary between Nevada and California. The most notable changes were in 1864 when Nye County was formed, thus reducing Esmeralda County to less than half its original size, and in 1911 when Mineral County was established, thereby again reducing the size of Esmeralda County by about half. The boundaries have remained stable since 1911. The area of the county is now 3,570 square miles. Esmeralda County, as well as the rest of Nevada, was originally settled by prospectors and miners and has been sustained throughout most of its history by mining. The total recorded mineral production was at least $122 million through 1962 and was probably considerably more depending on the figure assigned to Goldfield. However, the value of mineral commodities produced has dropped markedly in recent years, from $1,140,441 in 1959 to $657,669 in 1962. Mining operations during 1962 resulted in the production of diatomite from a deposit adjacent to U.S. Highway 6 at the western boundary of the county; talc and soapstone from deposits in the Sylvania Mountains; quicksilver from deposits on the east flank of the White Mountains; silver from a deposit at the north end of the White Mountains; and sand and gravel for road construction and maintenance.

LOCATION, ACCESSIBILITY, AND CULTURE

Esmeralda County lies in the southwestern part of Nevada adjacent to the California border and is readily accessible by the network of hard-surfaced all-weather highways shown in figure 1. In addition to the U.S. and State highways, numerous roads, ranging in quality from well-graded graveled roads to dirt tracks in the sagebrush, provide access to nearly all parts of the county. Moreover, many alluvial fans and washes can be negotiated by four-wheel-drive vehicle.

The county is very sparsely populated. The total estimated population in January 1962 was about 500. The principal centers of population include Goldfield, the county seat, with an estimated population of about 300; Fish Lake Valley, an area of prosperous ranching activity in the shadow of the White Mountains; and the villages of Silver Peak, Lida, and Gold Point. Tonopah, the county seat of Nye County, lies adjacent to Esmeralda County and is the principal business center of the area.

GEOGRAPHIC NAMES

Many prominent topographic features in Esmeralda County have apparently gone without names up to the present time. Inasmuch as a scarcity of place names makes it difficult to describe the geology of the county clearly and without ambiguity, we have introduced nine new geographic names to aid us in this respect. The new names, all of which have been formally approved by the United States Board on Geographic Names, are: (1) Angel Island, (2) Clayton Ridge, (3) General Thomas Hills, (4) Goldfield Hills, (5) Montezuma Range, (6) Mount Jackson Ridge, (7) Oasis Divide, (8) Paymaster Ridge, and (9) Weepah Hills. These features are shown on figure 1 and plate 1.

Most of the names are from nearby already named features (i.e., Montezuma Range from Montezuma Peak, etc.). The term Goldfield Hills was used informally in a report by Ball (1907). So far as the writers are aware, none of the new names is in conflict with local usage.

TOPOGRAPHY, DRAINAGE, AND WATER SUPPLY

The overall topography of Esmeralda County is dominated by several arcuate ranges having southward convexity and by the intervening, but less clearly arcuate, valleys. From north to south (fig. 1) these arcuate ranges are: (1) the Monte Cristo and Cedar Mountains; (2) Silver Peak and Palmetto Mountains, and the Montezuma Range; (3) Magruder Mountain and Mount Jackson Ridge; (4) Slate Ridge; and (5) Gold Mountain. Prominent valleys that separate the above-mentioned mountains include (1) Big Smoky Valley and Columbus Salt Marsh, which is the southern end of Soda Springs Valley; (2) Fish Lake Valley, Palmetto Wash, and an unnamed valley north of Mount Jackson Ridge; (3) an unnamed valley south of Mount Jackson Ridge; (4) Oriental Wash, a tributary of Death Valley of the adjacent part of California; and (5) Grapevine Canyon. Dominating the central part of the county is Clayton Valley, which has an elliptical rather than arcuate shape.

Esmeralda County includes Boundary Peak, altitude 13,145 feet, at the north end of the White Mountains and the highest point in Nevada. The lowest point is at the California State line in Oriental Wash where the altitude is about 3,700 feet. The general relief between valley bottoms and the crests of adjacent ranges is on the order of 3,000 to 4,000 feet.

Water is scarce in most parts of Esmeralda County. The only permanent streams are those draining from the White Mountains into Fish Lake Valley. They provide, along with water wells, a supply that is adequate for the existing level of agriculture. The overflow from Fish Lake Valley drains northward at times into Columbus Marsh, and there is probably also some underground drainage into the marsh. But although the water level in Columbus Marsh stands about at the surface and water is plentiful, it is brackish and not potable. Therefore, the proprietors of Coaldale Inn at Coaldale Junction, near the southeast edge of Columbus Marsh, must haul drinking water from a source in the mountains 25 miles to the west.

Water is likewise abundant in Clayton and Big Smoky Valleys, but here also is too brackish for human consumption. The village of Silver Peak formerly hauled drinking water from a spring in the southern part of the Silver Peak

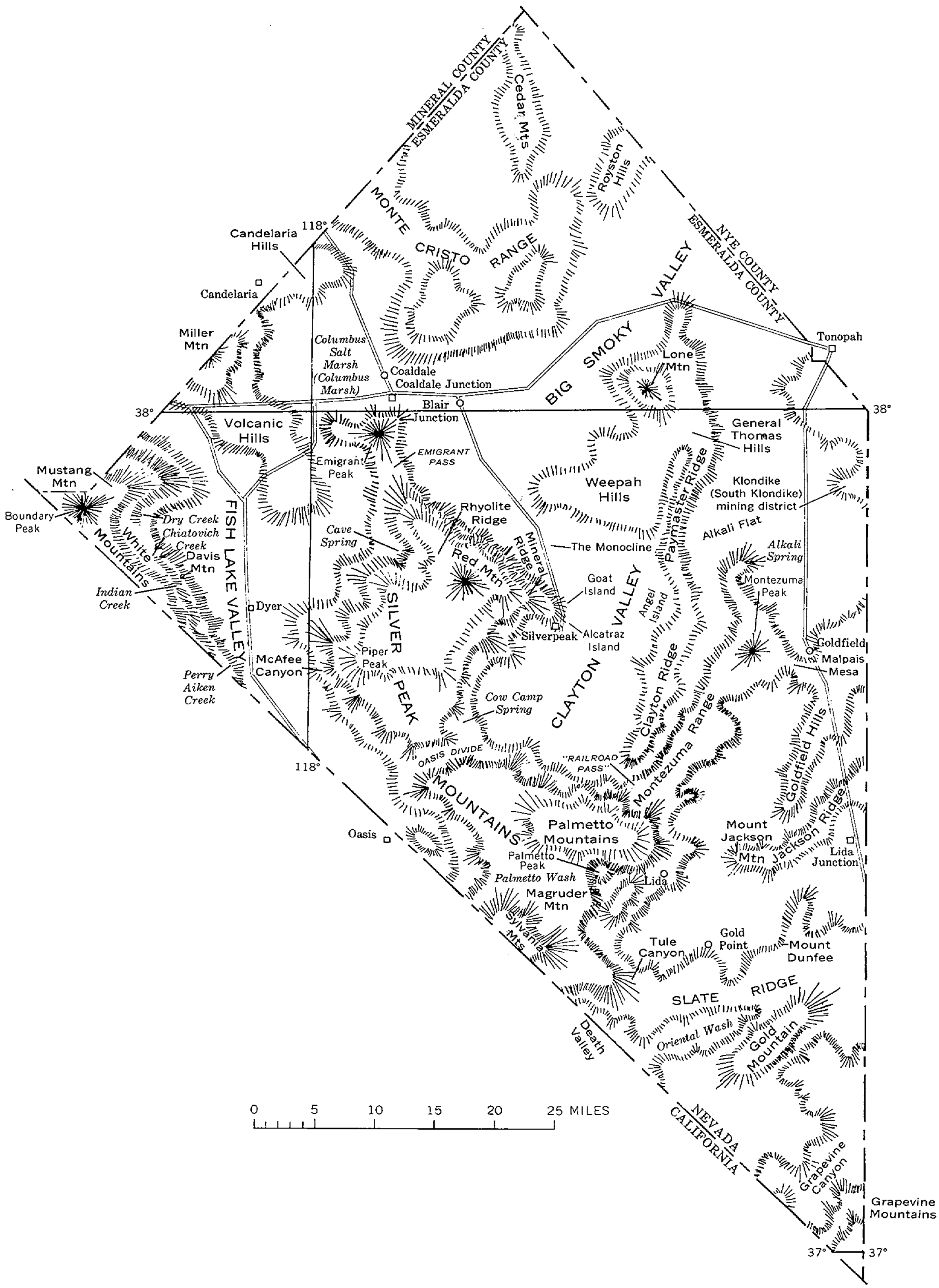

Figure 1. Index map of Esmeralda County, Nev., showing physiographic features and major roads.

Mountains, but now utilizes a water supply encountered during recent exploration of the Sixteen-to-One mine. Goldfield obtains adequate water for present requirements from wells and from springs just west of town, but during the early 1900's when the mines were operating at full capacity an 8-inch pipeline carried water to Goldfield from springs on the south flank of Magruder Mountain, 30 miles to the southwest. Several good springs occur in the vicinity of Lida, and water is obtainable from springs and wells in Palmetto Wash.

CLIMATE AND VEGETATION

The climate of Esmeralda County is arid to semiarid, and temperature ranges are extreme. Snow falls during the winter months, but except in the Silver Peak, Palmetto, and White Mountains does not restrict access for more than a few days after a storm. Climatic data for three weather stations in Esmeralda County during the years 1956 through 1962 are summarized in table 1. These stations are all at comparatively low altitudes, and somewhat greater precipitation and lower temperatures prevail in mountainous areas of the county.

TABLE 1. Summary of climatic data for the years 1956–1962, Esmeralda County.
[U.S. Department of Commerce, Weather Bureau Climatological Data, Nevada Annual Summaries]

	COALDALE (Approximate altitude, 4,650 feet)						DYER (Approximate altitude, 4,850 feet)						GOLDFIELD (Approximate altitude, 5,689 feet)					
	Temperature in degrees Fahrenheit						Temperature in degrees Fahrenheit						Temperature in degrees Fahrenheit					
Year	Jan. avg.	July avg.	Annual avg.	High	Low	Annual precipitation in inches	Jan. avg.	July avg.	Annual avg.	High	Low	Annual precipitation in inches	Jan. avg.	July avg.	Annual avg.	High	Low	Annual precipitation in inches
1956	40.6	77.6	...	105	1	1.93	35.9	71.2	...	103	−9	3.65	...	...	...	...	...	...
1957	29.6	77.0	53.9	104	−5	4.79	24.8	71.2	50.1	100	−17	8.28	...	...	...	...	...	...
1958	34.7	78.5	51.6	105	...	3.13	32.1	71.6	51.4	103	3	4.21	...	...	...	...	...	...
1959	...	...	...	...	...	...	33.9	76.3	52.3	103	−6	2.33	37.0	70.5	49.2	100	6	2.87
1960	...	...	...	...	...	...	29.0	74.7	52.7	104	−7	6.37	27.9	75.2	51.4	99	−2	6.55
1961	...	...	...	...	...	...	30.8	75.8	51.6	106	0	2.83	32.9	76.5	50.8	97	0	4.47
1962	...	...	...	...	...	...	27.3	65.8	50.4	100	−21	5.53	28.4	72.8	51.9	96	−10	6.23

Vegetation on the lower slopes and in the valleys consists of sagebrush and other desert plants. Many of these plants bloom in April and May, and the resulting display of color is often spectacular. Joshua trees and small cacti of the prickly pear variety grow as far north as the latitude of Goldfield at the lower elevations, and trees of the poplar family grow around some springs. Piñon and juniper appear above about 6,500 feet, where most of the ranges have a mixture of these two types of small trees. Generally, piñons become increasingly abundant with increasing elevation. In the White Mountains, at an altitude of around 7,500 feet, small groves of quaking aspen appear along streams, and sparse evergreens dot the hillsides.

PREVIOUS WORK

Geological observations in Esmeralda County date back to 1866 when J. E. Clayton collected fossils at Silver Peak that were first thought to be Silurian or Devonian but were later identified by C. D. Walcott as Cambrian (Spurr, 1906b, p. 19). In 1897, some fossils from Tertiary beds containing coal seams at the north end of the Silver Peak Range were collected and reported by Knapp (1897, p. 133).

The first geologic mapping in Esmeralda County was begun in 1899 by H. W. Turner of the U.S. Geological Survey, and in 1900 a map showing the distribution of the Tertiary Esmeralda Formation was published (Turner, 1900). A geologic map of the Silver Peak 30-minute quadrangle, by Turner, was published in generalized form as part of a report by Spurr (1906b) who studied the ore deposits of the quadrangle. Spurr (1905) had earlier reported on the Tonopah mining district.

The next geologic work was by Ball (1907) who, after a single field season in 1905 with two assistants, succeeded in making a good reconnaissance geologic and topographic map covering an area of 8,550 square miles in southwestern Nevada and southeastern California. Most of the eastern part of Esmeralda County is included on this map. Ball's work was done under the general supervision of F. L. Ransome who himself began a detailed study of the Goldfield mining district in 1905 and published the results of this work (1909a). Other publications followed: Hance on the Coaldale coal field (1913); Knopf on Divide silver mining district (1921) and Candelaria silver mining district (1922). During 1922–1937, H. G. Ferguson, S. W. Muller, and S. H. Cathcart made a reconnaissance geologic map of 7,700 square miles constituting the Hawthorne and Tonopah 1° sheets. This work dealt mainly with pre-Tertiary rocks. They also made detailed studies of critical areas within this larger area. The results of this work, which includes approximately the northern third of Esmeralda County, were published by Ferguson and Muller (1949) and Ferguson and others (1953, 1954).

The structural position of Goldfield in the continental framework was discussed by Billingsley and Locke (1939). Work during World War II resulted in reports on the Coaldale mining district by V. H. Johnson and R. C. Robeck (written communication, 1944), and on the B & B and other quicksilver deposits in the Fish Lake Valley district by Bailey and Phoenix (1944). Wilson (1944) gave the results of geochemical studies made in the Goldfield district. A further contribution to the geology and ore deposits of Goldfield was made by Searls (1948).

During the 1950's, reports were published on the Black Rock manganese deposit (Benson, 1950) and on the ground-water potential in Fish Lake Valley (Eakin, 1950). The most recent published reports include those of McKee and Moiola (1962) on the Precambrian and Cambrian rocks of south-central Esmeralda County; Albers and Stewart (1962) on the Precambrian and Cambrian stratigraphy of the county; McKee (1968) on the geology of the Magruder Mountain area in the southwestern part of the county; and Robinson and others (1968) on Tertiary rocks in the Silver Peak area.

FIELD WORK AND ACKNOWLEDGMENTS

This report is based on field work done during the period 1960 through 1962. J. P. Albers and W. L. Emerick began work in early July 1960, but Emerick was transferred to work in the Nevada Test Site shortly thereafter. J. H. Stewart was assigned to the project in mid-August and remained until completion of field work in October 1962. E. H. McKee assisted with the field mapping for several weeks during 1961 and 1962. Altogether, about 17 man-months were required to complete the field work, which involved mapping of approximately two-thirds of the county. Mapping was done on air photos at scales of 1:60,000 and 1:48,000. The geologic map was compiled and adapted by Albers from the sources shown on plate 1. The first compilation was at 1:62,500 scale on enlarged AMS sheets. This was then photographically reduced and generalized where necessary to the present map scale of 1:250,000. Description of the Precambrian through Mesozoic stratified rocks in the text is by Stewart, and the remainder of the text is by Albers.The progress of field work was very greatly expedited by the work of C. A. Nelson, who, during the 1950's, had worked out the succession of Lower Cambrian rocks in the Inyo Range west of Esmeralda County, and also by the work of E. H. McKee, who, in his study of the Magruder Mountain area in 1959 and 1960, had ascertained that the Lower Cambrian section is essentially the same as that in the Inyos. Field conferences with Nelson and McKee in mid-1960 and on several subsequent occasions provided the authors with the background of detailed stratigraphic knowledge without which, in view of the complex structural relations, a much longer time would have been required to complete the field work.

R. J. Moiola, Paul Robinson, James Dover, and J. S. Wilson, as well as E. H. McKee, all kindly supplied their unpublished thesis maps (see plate 1) to the authors for use in compilation, and a map of part of the Red Mountain mining district, Silver Peak Mountains, was supplied through the courtesy of Arthur Baker III of the Callahan Mining Corp. Useful discussions relating to mutual geologic problems were also held in the field on several occasions with Moiola and Robinson. It is a pleasure to acknowledge the cooperation of all the above individuals.

Fossil determinations were made by Mackenzie Gordon, Jr., C. A. Nelson, A. R. Palmer, and R. J. Ross of the U.S. Geological Survey. X-ray diffractometer analyses of two samples of tuff were made by Anna O. Shepard, and potassium-argon age determinations are by R. W. Kistler, Edwin H. McKee, John D. Obradovich, and Marvin A. Lanphere of the U.S. Geological Survey. Profitable discussions concerning general geologic problems were held in the field with H. R. Cornwall, F. J. Kleinhampl, R. S. Smith, and R. E. Wallace, also of the U.S. Geological Survey.

R. O. Camozzi of U.S. Milling and Minerals Corp. supplied samples of ore from the Mohawk mine and conducted the writers on a visit through this mine and the Ohio mine at Gold Point.

James A. Rhodes of Stauffer Chemical Co. provided the log of a drill hole put down in Tertiary rocks in the Cave Spring area of the Silver Peak Mountains.

STRATIGRAPHY

Sedimentary rocks ranging in age from Precambrian to Quaternary are widely exposed in Esmeralda County. Strata from every period except Silurian, Devonian, Pennsylvanian, and Cretaceous have been definitely recognized (fig. 2).

Turner (1900, 1902, 1909) made the first comprehensive survey of the stratigraphy of Esmeralda County. He recognized strata of Precambrian, Cambrian, Ordovician, Carboniferous, Tertiary, and Quaternary Age and named the Silver Peak, Emigrant, and Palmetto Formations of Cambrian and Ordovician Age. The term Silver Peak Formation (or Group as it was later called by Walcott, 1908) has since been abandoned (Nelson, 1962, p. 143), but the terms Emigrant Formation and Palmetto Formation are still in use and are used in this report. Spurr (1906b) further described the Cambrian and Ordovician strata, largely following the work of Turner (1902). In 1908, Walcott described a fossiliferous section of Lower Cambrian strata in the northeastern part of the Palmetto Mountains.

Publications describing the strata that crop out in the northern part of the county are by Muller and Ferguson (1936, 1939), Ferguson and Muller (1949), and Ferguson and others (1953, 1954). They named the Diablo Formation of Permian Age, the Candelaria and Excelsior Formations of Triassic and Triassic(?) Age, respectively, and the Dunlap Formation of Jurassic Age; all these names are used in this report.

The names used for strata of Precambrian and Cambrian Age are the same as those used by Nelson (1962, 1966a and b) in the White and Inyo Mountains in California and subsequently used in Esmeralda County by McKee and Moiola (1962) and by Albers and Stewart (1962). Some of the names used by Nelson (1962) were new, but some had been previously proposed by other geologists.

PRECAMBRIAN STRATA

Precambrian strata exposed in Esmeralda County consist of, in ascending order, the Wyman Formation, Reed Dolomite, and Deep Spring Formation.

Wyman Formation

The Wyman Formation includes the oldest rocks exposed in Esmeralda County. The true sedimentary base of the formation is nowhere exposed. In some places the base of the Wyman is an intrusive contact with younger granitic rocks; in other places it is a fault or a contact with Tertiary

Pre-Tertiary rocks exposed in Esmeralda County, Nevada

Age	Epoch	Main part of Esmeralda County	Thickness in feet	Northern Grapevine Mountains	Thickness in feet	Miller Mountain area	Thickness in feet
Jurassic	Lower and Middle	Dunlap Formation	Only few hundred feet exposed				
		UNCONFORMITY					
Triassic(?)	Middle	Excelsior Formation	Several thousand				
		UNCONFORMITY					
Triassic	Lower	Candelaria Formation	3,200+				
		UNCONFORMITY					
Permian		Diablo Formation	200-500				
Mississippian		UNCONFORMITY		Shaly rocks	Only few hundred feet exposed		
				FAULT			
Ordovician		Palmetto Formation	Several thousand	Pogonip Group	Only few hundred feet exposed		
Cambrian	Middle and Upper	Emigrant Formation	Several thousand	Nopah Formation	Only few hundred feet exposed	Siliceous hornfels	1,000+
Cambrian	Lower	Mule Spring Limestone	400-500			Marble	600+
						FAULT	
Cambrian	Lower	Harkless Formation (includes equivalent of Saline Valley Formation at top)	3,500			Harkless(?) Formation	1,200+
Cambrian	Lower	Poleta Formation	1,000+-1900			Poleta(?) Formation	625+
Precambrian	Upper	Campito Formation	2500(?)			Campito Formation	1,800+
Precambrian	Upper	Deep Spring Formation	1,500				
Precambrian	Upper	Reed Dolomite	1,560				
Precambrian	Upper	Wyman Formation	1,350+				

Figure 2. Pre-Tertiary rocks exposed in Esmeralda County.

or Quaternary units. The total thickness of the formation and the complete succession of lithic units within the formation are, therefore, not known.

The total outcrop area of the Wyman Formation is small, but outcrops are scattered throughout the southern three-fourths of the county. The formation is exposed in the following areas: (1) on the flanks of eastward-trending granitic bodies in the Gold Point, Slate Ridge, and Gold Mountain area, (2) in small outcrops near Oriental Wash and in Tule Canyon, (3) in a northwest-trending belt 2 to 4 miles southwest of Palmetto Wash, (4) on Mineral Ridge, (5) in the northern part of the Weepah Hills, (6) on the northeast and southwest flanks of the Lone Mountain pluton, and (7) on the east side of the White Mountains. The Wyman Formation characteristically occurs within or on the flanks of granitic plutons in the county. In the Slate Ridge and Gold Mountain areas and on Lone Mountain the Wyman forms belts along the flanks of the granitic plutons, and the strata are grossly concordant with the contact of the pluton, although most of the formation is almost certainly cut out by the pluton.

The Wyman Formation is composed of phyllitic siltstone and silty claystone and minor amounts of limestone, sandy limestone, limy siltstone, and limy, very fine-grained sandstone. These strata are somewhat metamorphosed everywhere and commonly grade into phyllite, schist, marble, and calc-silicate and siliceous hornfels. The phyllitic siltstone is medium gray, olive gray, or dark greenish gray, and is composed of silt-sized quartz particles mixed with fine-textured biotite, chlorite, and muscovite. An original fine lamination is noticeable locally in the phyllitic siltstone, but in some places the original stratification is obliterated by a secondary cleavage that is commonly at an angle to the stratification. Interlayered with the phyllitic siltstone are units of limestone or marble that are mostly from less than an inch to 20 feet thick but are locally at least 50 feet thick. Several limestone units in the top 250 feet of the Wyman Formation on Mount Dunfee contain limestone pellets and pisolites.

Layers of sandy limestone and limy sandstone also occur interstratified with the phyllitic siltstone. These layers are mostly a quarter of an inch to 8 inches thick. The sandy limestone and limy sandstone is light to medium gray, yellowish brown weathering, distinctly and evenly laminated, and composed of very fine grains of quartz and minor feldspar set in a calcite matrix. Orthoclase appears to constitute 10 to 15 percent of some of these rocks. Plagioclase is present although in very minor amounts.

As a whole, the Wyman Formation is well bedded. The fine and even bedding and intricate interlayering of the lithologic types are the distinctive characteristics of the formation.

Near exposed igneous contacts and locally elsewhere, the Wyman Formation is metamorphosed to phyllite, schist, siliceous hornfels, calc-silicate hornfels, and marble. Commonly calc-silicate hornfels beds are closely interlayered with siliceous hornfels, reflecting the original interlayering of limy sandstone (or sandy limestone) and siltstone. Within a few hundred feet of a contact with an igneous pluton, rocks consisting mostly of garnet or epidote are common. On Mineral Ridge and locally elsewhere the Wyman Formation is intensely folded on a small scale, commonly with many recumbent folds. In addition, on Mineral Ridge the Wyman Formation is cut by many quartz and aplite dikes, and locally pegmatitic masses of quartz and feldspar have developed in axial parts of small folds, or in places elsewhere. In such places the rock resembles a migmatite.

The exposed thickness of the Wyman Formation on Mount Dunfee is 967 feet (fig. 3) and on the east side of Lone Mountain is 1,354 feet. These thicknesses are incomplete because the base of the formation is not exposed. Thicker sections of the formation probably occur on the flanks of some of the granitic plutons, but these sections were not measured. Nelson (1962, p. 140) lists a minimum thickness of 9,000 feet for the Wyman Formation in the White and Inyo Mountains, and the base of the formation is not exposed there.

The contact of the Wyman Formation and the overlying Reed Dolomite appears to be conformable (Albers and Stewart, 1962) where it has been observed on Mount Dunfee and on the east side of Lone Mountain. On Mount Dunfee, some of the limestone in the top 250 feet of the Wyman Formation contains pellets and pisolites that closely resemble structures seen in the overlying Reed Dolomite, and in addition the limestone in the top part of the Wyman Formation in this area is locally altered to a dolomite indistinguishable from the Reed Dolomite. These lithologic similarities between the strata near the top of the Wyman and in the Reed suggest a transitional sequence from one to the other. Nelson (1962, p. 140–141), however, has indicated that the contact between the Wyman and Reed is an unconformity in the White and Inyo Mountains. As suggested earlier (Albers and Stewart, 1962), perhaps the wide lithologic variation in the topmost part of the Wyman, as observed by Nelson (1962, p. 141), is due to a combination of original lenticularity of beds within the Wyman and to thrust relation between the Wyman and Reed, rather than to an unconformity.

Reed Dolomite

The Reed Dolomite crops out at scattered localities in the southern three-fourths of the county. These outcrops are (1) in the Gold Point, Slate Ridge, and Gold Mountain areas, (2) on Palmetto and Magruder Mountains, (3) 1 to 3 miles southwest of Palmetto Wash, (4) near Cow Camp Spring, (5) on Mineral Ridge, (6) in the Weepah Hills, (7) on the west side of Clayton Ridge, (8) 2 miles northwest of Montezuma Peak, (9) on the northeast and southwest flanks of the Lone Mountain pluton, and (10) on the east side of the White Mountains.

The Reed Dolomite is mostly a homogeneous sequence of white to medium-gray, yellowish-gray, and pale-yellowish-brown, medium to coarsely crystalline dolomite. At most localities, the dolomite appears structureless, but this characteristic may be largely due to movement that has obliterated the original bedding. On Mount Dunfee, probably the best exposure of the Reed Dolomite in Esmeralda County, beds from 1 to 4 feet thick are common in much of the formation and evenly laminated layers occur

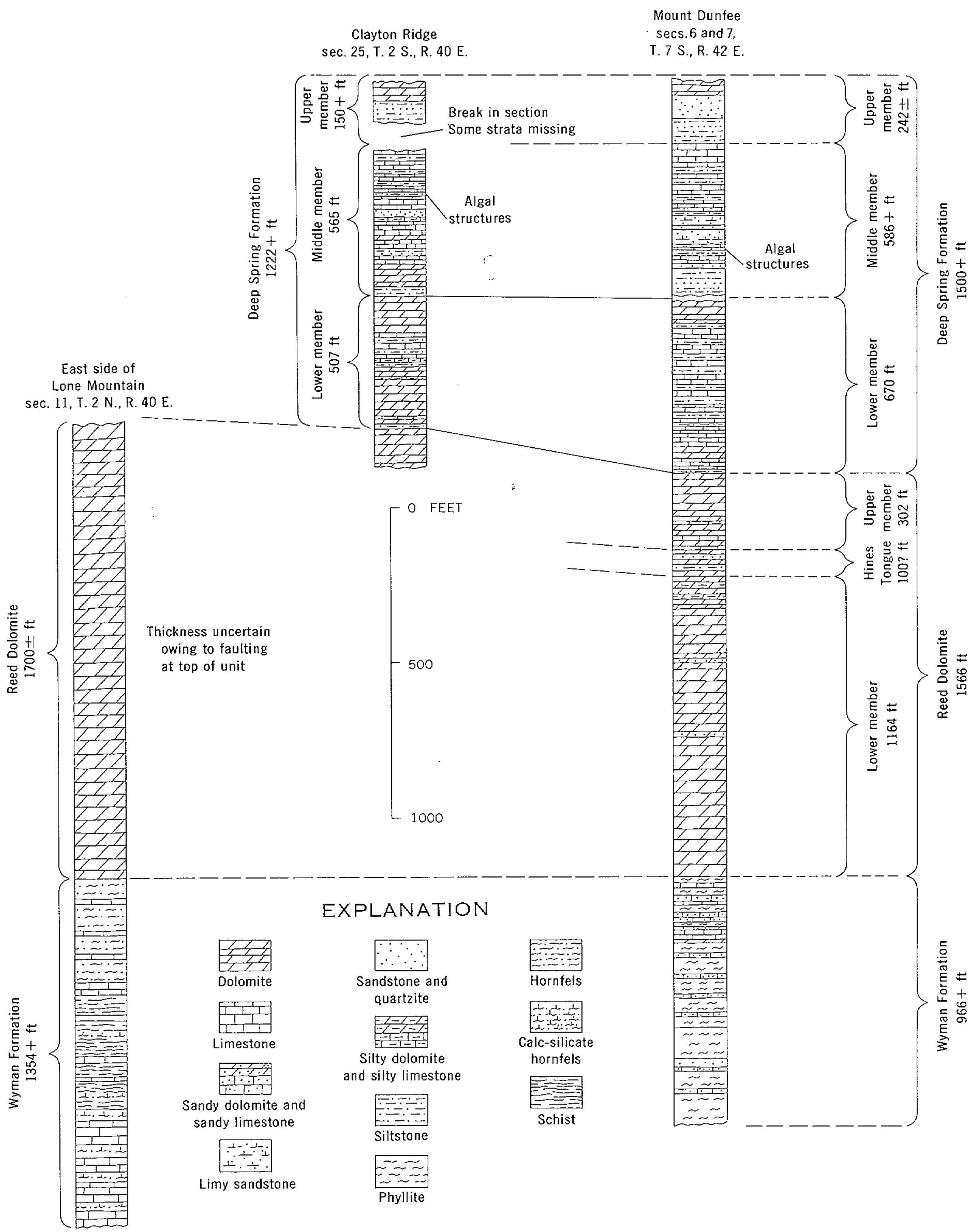

Figure 3. Correlation of the Wyman Formation, Reed Dolomite, and Deep Spring Formation.

locally. Also on Mount Dunfee, oölites, pisolites, and irregular pellets occur in parts of the lower 1,000 feet of the formation; these structures may be, in part, of algal origin.

On Mount Dunfee, three members are recognized in the Reed Dolomite. These units have been previously described (Nelson, 1962, p. 141) in the Inyo and White Mountains, Calif., and consist of a lower member, a middle member which has been formally named the Hines Tongue, and an upper member. The lower and upper members consist dominantly of dolomite, the characteristic lithic type in the formation. rare silty or sandy dolomite occurs in the top half of the lower member, and some sandy limestone occurs in the bottom 115 feet of the upper member (fig. 3). The Hines Tongue consists of medium-gray to pale-yellowish-brown dolomite and sandy dolomite; very pale-orange, very fine-grained dolomitic sandstone and quartzite; and minor amounts of yellowish-gray to pale-yellowish-brown siltstone. The Hines Tongue is recognized only on Mount Dunfee, and even there it is an inconspicuous unit only about 100 feet thick. It apparently grades out northward in the county into dolomite indistinguishable from the remainder of the formation (fig. 3). A similar northward lateral gradation of the Hines Tongue has been described by C.A. Nelson (oral communication, 1963) in the Inyo and White Mountains.

The Reed Dolomite is over 1,500 feet thick (fig. 3) on Mount Dunfee. A thickness of 2,665 feet was measured east of Lone Mountain, but here the top 1,000 feet may be a duplication and the actual thickness of the formation may be only about 1,700 feet. Even the latter figure is suspect, owing to the difficulty of recognizing faults in the homogeneous dolomite of the Reed.

In the mapping of Esmeralda County, the contact between the Reed Dolomite and Deep Spring Formation was placed at the change from the thick-bedded or structureless dolomite of the Reed to the distinctly bedded dolomite, limestone, and siliceous clastic units of the Deep Spring Formation. This contact, although in places transitional and difficult to locate precisely, is, nonetheless, mappable and represents a noticeable lithologic change. The bedded units in the Hines Tongue of the Reed, however, are difficult to distinguish from bedded units in the Deep Spring Formation and in places, particularly in faulted areas, the Hines Tongue might have been mapped as part of the Deep Spring Formation. The Hines Tongue, however, has been definitely identified only on Mount Dunfee and may occur only in that general area.

Deep Spring Formation

The Deep Spring Formation is a heterogeneous unit about 1,800 feet thick containing siltstone, sandstone, limy or dolomitic sandstone, quartzite, sandy limestone or dolomite, and limestone or dolomite. It crops out in the following areas: (1) on Mount Dunfee and 6 miles to the east-southeast, (2) on Magruder Mountain and several miles to the southwest, (3) on the south side of Palmetto Mountain, (4) on Mineral Ridge, (5) on the west side of Clayton Ridge, (6) on the west side of the Montezuma Range, and (7) near Lone Mountain.

Three members are recognized in the Deep Spring Formation in Esmeralda County. These members are correlative with the three members of the Deep Spring Formation mapped by Nelson (1962, p. 141; 1966a) in the White and Inyo Mountains and are best exposed on Mount Dunfee and on the west side of Clayton Ridge.

The lower member is a minimum of 670 feet thick on Mount Dunfee and about 507 feet thick on Clayton Ridge. The member consists of medium-gray, finely crystalline, very thinly bedded limestone; light-gray, medium-gray, and very pale-orange, finely to coarsely crystalline, laminated to thick-bedded dolomite; minor amounts of olive-gray and greenish-gray siltstone; and rare calcareous sandstone and quartzite. Some limestone contains very fine (locally fine to medium) grains of quartz, and other beds contain irregular small calcareous pellets and rod structures about a quarter of an inch in diameter. The dolomite occurs mostly near the base and at the top of the member. The dolomite near the base resembles that in the underlying Reed Dolomite and represents a transitional sequence into the Reed. The dolomite at the top of the member is about 100 feet thick on Mount Dunfee and about 135 feet thick on Clayton Ridge (fig. 3). It is considered to be equivalent to a dolomite unit (C. A. Nelson, oral communication, 1963) that forms the top of the lower member of the Deep Spring Formation in the White and Inyo Mountains. The amount of carbonate in the lower member increases northward between Mount Dunfee and Clayton Ridge (fig. 3). A similar increase in the amount of carbonate in the Deep Spring Formation northward was noted by C. A. Nelson (1962, p. 141; written communication, 1963) in the White and Inyo Mountains.

The middle member of the Deep Spring Formation is a minimum of 586 feet thick on Mount Dunfee and about 565 feet thick on Clayton Ridge. The member consists of medium-gray, very finely to finely crystalline, locally oölitic limestone; greenish-gray, olive-gray, and very pale-orange siltstone; yellowish-gray, pale-yellowish-brown, and very light-gray, very fine to fine-grained quartzite; and calcareous sandstone. Some very pale-orange, very finely to medium crystalline dolomite occurs in the member on Clayton Ridge. The member contains more quartzite and siltstone than the lower member and less carbonate rock. The amount of carbonate rock increases in the middle member between Mount Dunfee and Clayton Ridge, following the same trend as in the lower member. Biscuit-shaped algal masses occur in limestone 167 to 184 feet above the base of the middle member on Mount Dunfee and from 412 to 437 feet above the base of the member on Clayton Ridge. Intraformational pebble and cobble conglomerate with flat disc-shaped sandy limestone fragments occur in several layers from 125 to 148 feet above the base of the middle member on Mount Dunfee, and a few cross-stratified quartzite layers occur in the basal 123 feet of the member in the same area.

The upper member of the Deep Spring Formation is a minimum of 242 feet thick on Mount Dunfee and 150 feet in a partial section on Clayton Ridge. The lower part of the member consists of grayish-olive, greenish-gray, and medium-gray siltstone and very fine-grained silty quartzite.

The top of the member consists of a medium-gray, finely crystalline, fairly well-bedded dolomite unit about 50 to 70 feet thick. This dolomite is probably correlative with a carbonate unit (C. A. Nelson, oral communication, 1963) at the top of the Deep Spring Formation in the White and Inyo Mountains.

The sequence of green or gray siltstone and quartzite capped by a light-colored carbonate unit is diagnostic of the upper member of the Deep Spring Formation. The dark siltstone and quartzite units are, however, very similar to strata in the Campito Formation that overlie the Deep Spring Formation and without the presence of the intervening carbonate unit could not be readily distinguished from the Campito Formation.

The contact between the Deep Spring Formation and the overlying Campito Formation is apparently conformable in Esmeralda County and is marked by the change from dolomite or carbonate below (the carbonate at the top of the upper member) to olive-gray and greenish-gray siltstone and quartzite above.

PRECAMBRIAN AND LOWER CAMBRIAN STRATA

Campito Formation

The Campito Formation is divided into two members in Esmeralda County, a thick lower unit of dark-colored quartzite and siltstone, the Andrews Mountain Member, and a thin upper unit of greenish-gray siltstone, the Montenegro Member. The Montenegro Member contains the oldest fossils found in the county, although in the White and Inyo Mountains to the west a few fossils occur in the underlying Andrews Mountain Member.

The Campito Formation crops out (1) on the east end of Slate Ridge, (2) on Magruder Mountain, (3) on the north and south sides of the Palmetto Mountains, (4) on Mineral Ridge, (5) on the north end of Clayton Ridge, (6) on the Southwest side of Paymaster Ridge, (7) on the north end of the Montezuma Range, (8) in the Weepah Hills, and (9) on Miller Mountain.

The Andrews Mountain Member, the lower member of the Campito Formation, is composed of dark-greenish-gray, olive-gray, pale-brown, yellowish-gray, and grayish-red, very fine-grained quartzite and minor coarse siltstone. The rock characteristically weathers a dark color — commonly brownish black, greenish black, black or grayish red — and forms rubble-covered slopes that from a distance can be easily mistaken for rubble of basalt. The detrital grains in the quartzite are mostly quartz, although orthoclase constitutes as much as about 10 percent in some rocks, and minor amounts of plagioclase and opaque minerals occur. Hematite and limonite staining is common. The detrital grains are in a matrix of muscovite, biotite, and chlorite; the matrix may constitute as much as 30 percent of the rock. A carbonate cement occurs in some places, but generally the cement is siliceous. The quartzite is generally thinly laminated, although the stratification is difficult to see in most places. Layers of coarse siltstone ranging in thickness from six inches to 3 feet commonly are interstratified with the quartzite. Several coarse quartzite layers, ranging in grain size from very fine to very coarse and containing scattered quartz granules and pebbles as large as half an inch in diameter, occur in the member at a locality 5 miles east of Gold Point.

No complete or unfaulted section of the Andrews Mountain Member crops out in the county, and the thickness of the member was not determined. Perhaps the most complete outcrop of the member is 5 miles east of Gold Point, but even here a measured thickness would have little meaning due to the large number of faults in the area. Nelson (1962, p. 141) indicates that the Andrews Mountain Member in the White and Inyo Mountains is 2,500 to 2,800 feet thick, and the member probably has a similar thickness in Esmeralda County.

The Montenegro Member consists of dark-greenish-gray and greenish-gray siltstone, commonly metamorphosed and altered to pale-greenish-yellow, pale-olive, and grayish-olive phyllitic siltstone or phyllite. The siltstone is evenly laminated to thin bedded, although the bedding is commonly obscured by a secondary cleavage at an angle to the bedding. Markings, which are probably mostly worm trails and burrows, occur on bedding planes, but these are generally obliterated by the secondary cleavage. Thin limestone beds commonly occur in the top few hundred feet of the member.

The contact between the Andrews Mountain and Montenegro Members is transitional. In a section measured in the southern part of the Weepah Hills, 1,100 feet of transitional strata occur between the two members. Probably this transitional sequence is best assigned to the Andrews Mountain Member, because by this practice the Montenegro Member has a thickness similar to that in the White and Inyo Mountains (Nelson, 1962, p. 141).

The thickness of the Montenegro Member in the southern part of the Weepah Hills, excluding the transitional sequence, is about 1,035 feet. A thickness of 943 feet was measured in the southern part of Paymaster Ridge, but here the base of the member is cut by faults and is not easily determinable.

The Montenegro Member contains a fauna marked by the trilobite *Esmeraldina* [= *Holmia*] that has large and broad genal spines. These large spines are commonly in themselves indicative of the Montenegro Member. Fossils collected from the Montenegro Member by the writers are listed below. The fossils were identified by A. R. Palmer, except for 3–54–32 and 3–27–57, which were identified by C. A. Nelson.

3–20–17 (USGS collection 3735–CO), north-central part sec. 34, T. 1 S., R. 38 E., probably near base of Montenegro Member.
- *Esmeraldina* cf. *E. rowei* (Walcott)
- *Nevadia weeksi* Walcott
- undet. nevadiid

3–24–16J (USGS collection 3574–CO), NW¼ sec. 16, T. 2 S., R. 40 E., position in Montenegro Member not determinable.
- *Esmeraldina rowei* (Walcott)

1–51–42 (USGS collection 3782–CO), SW¼ sec. 9, T. 1 S., R. 37 E., probably about 200 feet below top of Montenegro Member.
Esmeraldina cf. *E. rowei* (Walcott)

3–54–32, SW¼ sec. 26, T. 2 S., R. 41 E.
Holmia [= *Esmeraldina*] *rowei*

3–27–57, SE¼ sec. 36, T. 1 S., R. 40 E.
Holmia [= *Esmeraldina*] sp.

670–86J (USGS collection 3652–CO), NW¼ sec. 15, T. 7 S., R. 42 E.
Judomia sp.
large calcareous brachiopod, *Kutorgina?*
small bivalves, probably undescribed conchostracan

670–203J (USGS collection 4131–CO), SW¼ sec. 2, T. 7 S., R. 42 E.
Judomia sp.

The Campito Formation is lithologically very similar to the stratigraphically higher Harkless Formation, and locally difficult to distinguish from the Harkless. The very fine-grained quartzite and coarse siltstone of the Andrews Mountain Member of the Campito Formation is lithologically similar to the quartzitic siltstone member of the lower part of the Harkless Formation. The greenish-gray siltstone of the Montenegro Member is apparently indistinguishable on a lithologic basis from the siltstone of the Harkless Formation. In areas where fossils occur in these units or where the overlying or underlying formations are in stratigraphic sequence, the two formations can be distinguished, but elsewhere their separation is difficult or impossible. As will be discussed in more detail later, some areas mapped as Campito Formation may actually be Harkless.

The contact between the Campito Formation and the overlying Poleta Formation is placed at the change from the dominantly siltstone, or phyllitic siltstone, of the Montenegro Member to the limestone of the lower member of the Poleta Formation. The limestone of the lower member of the Poleta Formation in most places contains archaeocyathids and is commonly oölitic. In a measured section in the southern part of Paymaster Ridge, a transition unit of limy siltstone and limestone 33 feet thick occurs between the Montenegro Member and the Poleta Formation and is assigned to the Poleta.

LOWER CAMBRIAN STRATA

Lower Cambrian strata include the Poleta Formation, Harkless Formation (locally including strata correlative to the Saline Valley Formation), and Mule Spring Limestone of Early Cambrian Age. These formations are exposed in much of the southern three-fourths of the county.

Poleta Formation

The Poleta Formation is one of the most distinctive units in the Precambrian and Lower Cambrian sequence. It is characterized by a variety of lithologic types, by the abundance of archaeocyathids, trilobites, and other fossils, and by its threefold division.

The Poleta Formation crops out fairly extensively in many parts of the county. The most widespread outcrops occur on Magruder Mountain and in the Weepah Hills, General Thomas Hills, Paymaster Ridge, Clayton Ridge, and Montezuma Range. The formation is also exposed (1) 4 to 8 miles east of Gold Point, (2) on the northeast side of the Palmetto Mountains and eastward to an area 3 miles east of Mount Jackson, (3) along Palmetto Wash and northward toward Oasis Divide, (4) near Cow Camp Spring, (5) west side of the Silver Peak Mountains 6 miles south of Piper Peak and also east of Dyer, (6) on the flanks of Mineral Ridge and westward into the Silver Peak Mountains, (7) on Alcatraz, Goat, and Angel Islands in Clayton Valley, and (8) possibly on Miller Mountain.

Lower, middle, and upper members are recognized in the Poleta Formation, but are not shown on the geologic map (pl. 1). The lower and upper members are dominantly limestone, whereas the middle member contains siltstone and minor quartzite and limestone.

The lower member is composed of medium- to light-gray, commonly oölitic limestone and, at least in some areas, interstratified units of greenish-gray, olive-gray, and moderate-brown siltstone. The limestone commonly contains abundant archaeocyathids, one of the most characteristic features of the member. Most of the limestone is indistinctly thin to very thin bedded, but some units have distinct and well-defined bedding. In most areas, the lower member contains at least one unit of siltstone interstratified with the limestone. These siltstone units range in thickness from a few feet to over 100 feet.

The lower member appears to be variable in thickness and lithologic character from area to area, but such variability is difficult to demonstrate because the member is generally highly faulted. At a locality 6.5 miles N. 5° W. of Lida, the lower member, in what appears to be an almost complete section, consists of 410 feet of light-gray, finely crystalline, locally oölitic limestone. No siltstone is present. In the Weepah Hills section (fig. 4), however, 1,063 feet of strata are assigned to the lower member, and here the member is divisible into three parts: (1) 143 feet of medium-gray limestone containing some very thin beds of light-brown dolomite, (2) 592 feet of nonresistant strata, the lower 243 feet of which are covered and the upper 349 feet of which consist dominantly of olive-gray and moderate-brown siltstone and phyllitic siltstone, and (3) 328 feet of medium-gray locally oölitic limestone containing a 39-foot yellowish-brown siltstone unit in the middle. Possible, although badly crushed, archaeocyathids occur in a limestone from 192 to 328 feet below the top of the lower member in the Weepah Hills section.

Possibly part of the strata in the Weepah Hills section have been misassigned. The 143-foot basal limestone and dolomite unit could be an unusually thick unit in the upper part of the Montenegro Member of the Campito Formation and, in this case, the overlying 592-foot silty sequence would also be assigned to the Montenegro Member. The lower member of the Poleta Formation would then consist of the remaining 328 feet of strata consisting of limestone and minor amounts of siltstone. Such an assignment is not

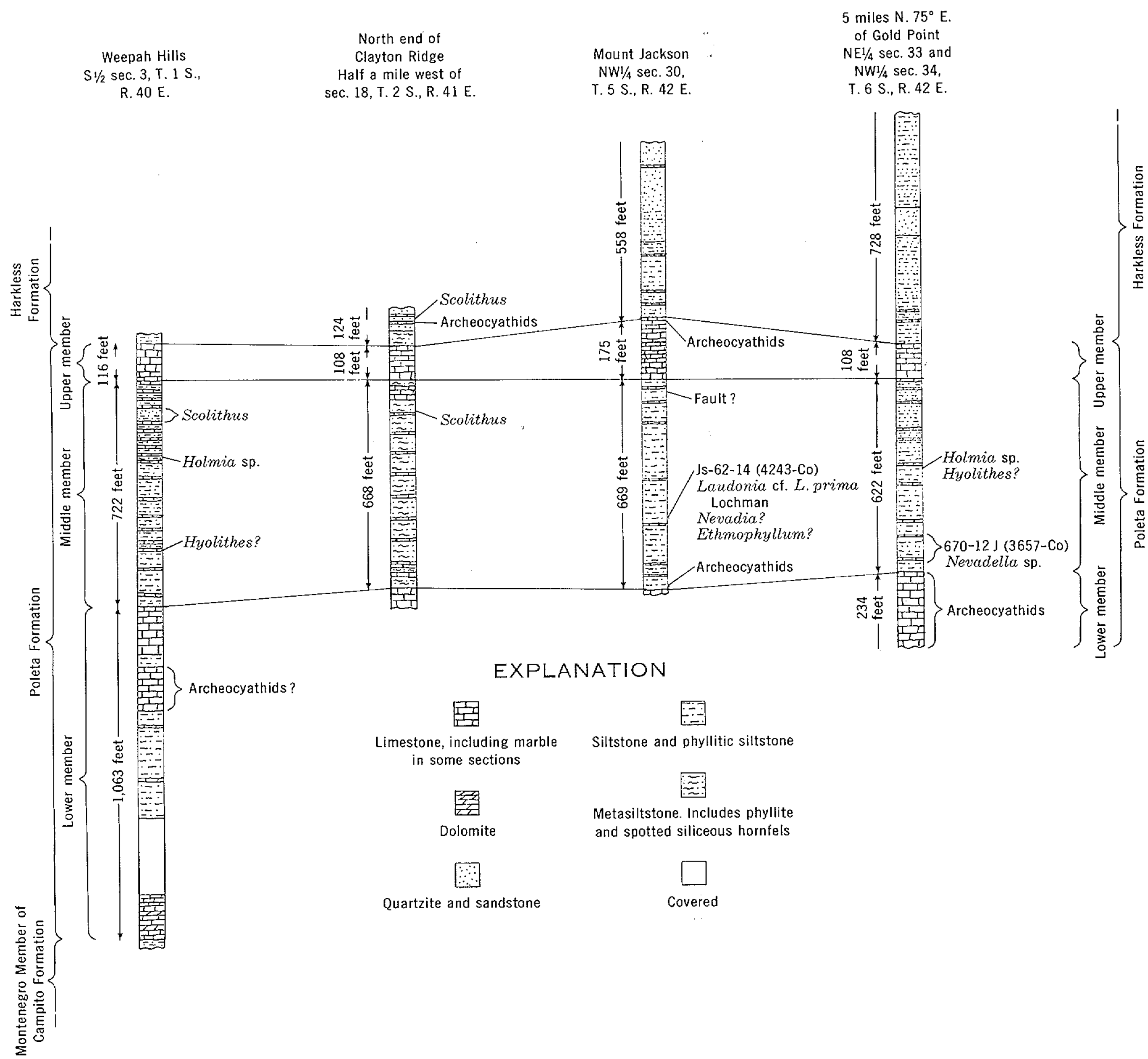

Figure 4. Correlation of Poleta Formation and lower part of Harkless Formation.

accepted, however, because elsewhere the Montenegro Member does not contain thick carbonate units.

The middle member of the Poleta Formation is composed of three main lithologic types: (1) siltstone and phyllitic siltstone, (2) limestone, and (3) sandstone or quartzite.

The siltstone and phyllitic siltstone are the dominant rock types of the middle member, which is grayish olive, pale olive, and locally pale yellowish brown or light brown. Trilobite remains are quite common in the siltstone in the lower third and locally elsewhere in the member.

The limestone of the member is medium gray and, to a lesser extent, grayish and orange, and aphanitic to medium crystalline. It occurs in layers from less than an inch to 15 feet thick interstratified with the siltstone. The member in most places contains one or two limestone beds from 1 to 15 feet thick that weather with a gray, almost blue, color and form ledges. These prominent limestone beds occur in the middle or upper half of the member and are helpful in identifying the member.

The sandstone or quartzite in the middle member is pale brown, light brown, and very pale orange, very fine grained, and generally evenly laminated. In places it grades into coarse siltstone. The sandstone commonly has a calcareous cement that constitutes about 20 percent of the rock. In some places the rock has a siliceous cement and is a quartzite. The dominant detrital grains are quartz, although orthoclase constitutes as much as 10 percent of some rocks, and plagioclase and muscovite occur in small amounts. In places worm borings *(Scolithus)* occur in quartzite or sandstone in the top 150 feet of the middle member. The quartzite and sandstone occur dominantly in the upper third of the middle member, and the presence of these quartzite and sandstone layers, coupled with the presence of the overlying limestone of the upper member of the Poleta Formation, form a distinctive and easily recognized part of the stratigraphic section.

The lithologic character of the middle member of the Poleta Formation changes, to a certain extent, from place to place in Esmeralda County. At a section northeast of Gold Point (fig. 4), the middle member is composed of siltstone with common limestone and, in the upper third, abundant quartzite. At the Mount Jackson section (fig. 4), only 8 miles to the north, most of the middle member is siltstone; only a few thin beds of limestone and sandstone occur. In general, limestone in the middle member increases in amount to the north in the county, although not between the sections just mentioned, and sandstone and quartzite decrease in amount to the north (fig. 4).

The upper member of the Poleta Formation is a medium-gray limestone that is indistinctly very thin to thin bedded. A few poorly preserved archaeocyathids occur locally. The upper member is generally about 100 feet thick (fig. 4).

The contact of the Poleta Formation and the overlying Harkless Formation is a sharp and easily recognized contact marking a change from limestone below to siltstone above.

Fossils collected from the Poleta Formation by the writers are listed below. All of the collections are from the middle member of the formation. Fossil collection 3–52–1 is questionably assigned to the middle member of the Poleta Formation; the collection is in a structurally complex area and could be Harkless Formation if it is not Poleta. Identifications are by A. R. Palmer, except for 670–206J and part of 3–22–31 (USGS collection 3567), which were identified by C. A. Nelson. 670–206J was collected by C. A. Nelson.

3–54–100 (USGS collection 3706–CO), NW¼ sec. 31, T. 2 S., R. 42 E., basal 100 feet of middle member.
- *Nevadella* cf. *N. addeyensis* (Okulitch)

JS–62–14 (USGS collection 4243–CO), north-central part sec. 30, T. 5 S., R. 42 E., 229 feet above base of middle member, Mount Jackson section.
- *Laudonia* cf. *L. prima* Lochman
- *Nevadia?* (a tiny specimen of nevadiid with long eyes)
- *Ethmophyllum?*

3–54–100A (USGS collection 3707–CO), NW¼ sec. 31, T. 2 S., R. 42 E., 240–260 feet above base of middle member, also a few specimens from 335 feet above base of member.
- *Holmia* sp.
- *Laudonia?* sp.

670–206J, NW¼ sec. 33, T. 6 S., R. 42 E., 332 feet above base of middle member. From stratigraphic section 5 miles N. 75 E. of Gold Point. Small *Holmia* of undescribed species. Collected by C. A. Nelson.

JS–62–35 (USGS collection 4240–CO), south-central part sec. 3, T. 1 S., R. 40 E., 470 feet above base of middle member, Weepah Hills section.
- *Holmia* sp.

670–5J (USGS collection 3653–CO), SW¼ sec. 33, T. 6 S., R. 42 E., indeterminate olenellid, cf. 3651–CO and 3660–CO.
- *Salterella?* sp.

3–54–51 (USGS collection 3651–CO), NE¼ sec. 22, T. 2 S., R. 41 E.
- *Nevadella* sp.
- *Fremontia* sp.
- *Laudonia prima* (Lochman)

670–95J (USGS collection 3660–CO), west-central part sec. 35, T. 6 S., R. 42 E.
- *Fremontia* sp.

670–12J (USGS collection 3657–CO), central part sec. 33, T. 6 S., R. 42 E.
- *Nevadella* sp.

3–54–102 (USGS collection 3568–CO), NE¼ sec. 36, T. 2 S., R. 41 E.
- *Nevadella* cf. *N. addeyensis* (Okulitch)

3–52–1 (USGS collection 3494–CO), south-central part sec. 30, T. 2 S., R. 41 E.
- *Olenellus* sp.

1–51–42B (USGS collection 3784–CO), SW¼ sec. 9, T. 1 S., R. 37 E.
- *Judomia* sp.
- *Laudonia* sp.

3–22–21 (USGS collection 3567–CO), west-central part sec. 13, T. 2 S., R. 39 E.

Judomia sp., identified by A. R. Palmer in one collection.

Olenellus sp., identified by C. A. Nelson in another collection.

Harkless Formation

The Harkless Formation is the most widely exposed formation of the Lower Cambrian sequence in Esmeralda County. It is exposed in all the ranges and mountains in the southern three-fourths of the county, although no outcrops occur south of the latitude of Gold Point.

In most of Esmeralda County, the Harkless Formation, which is 3,500 feet thick, is divisible into two members — a quartzitic siltstone member in the basal third of the formation and a siltstone member in the upper two-thirds. As will be discussed below, the siltstone member includes strata correlative to the Saline Valley Formation as described by Nelson (1962, p. 142), a formation lying above the Harkless Formation in the White and Inyo Mountains in California.

The quartzitic siltstone member consists dominantly of dark-greenish-gray to greenish-gray, laminated to very thin-bedded, coarse siltstone that is held together tightly by a siliceous cement. The basal few hundred feet of the member, however, are mostly fine siltstone and are not quartzitic. Limestone layers ranging in thickness from less than a foot to locally over 100 feet occur in the member, mostly in the lower half. The amount of limestone in the member varies greatly from area to area from only a few percent to as much as 10 or 15 percent of the member. Many of these limestone layers contain abundant remains of archaeocyathids, many of a large size. Some of the limestone layers that contain abundant archaeocyathids are lenticular, and these, at least, may have formed as "reefs." The lower 100 feet of the member in the Magruder Mountain area (McKee, 1957, p. 34, and fig. 10) and locally elsewhere contains a distinctive purple shale bed and purple limestone bed containing abundant pisolitic structures.

The quartzitic siltstone in the member is composed dominantly of coarse silt, although the grain size of the rock is near the boundary of coarse silt and very fine sand. The detrital grains are mostly quartz and are set in a matrix of chlorite, muscovite, and carbonate minerals. Commonly the rock is metamorphosed to a muscovite-chlorite-biotite-quartz hornfels containing ovoid spots rich in chlorite and biotite.

The thickness of the quartzitic siltstone member is 1,378 feet in the Weepah Hills section (fig. 5), and 1,203 feet in an incomplete section in the southernmost part of Paymaster Ridge near the Goldfield-Silver Peak road.

In the Mount Jackson area and northeast of Gold Point, the quartzitic siltstone member is not recognized even though strata in a comparable stratigraphic position are exposed. In these areas (fig. 4), the lower part of the Harkless Formation consists of pale-brown, light-brown, and light-olive-gray siltstone, and pale-yellowish-brown, light-brown, and grayish-red very fine-grained sandstone and sandy siltstone. One unit of sandstone and sandy siltstone in the Mount Jackson section is at least 325 feet thick. These brownish and reddish sandstone and sandy siltstone units probably represent a lateral lithologic change from the greenish-gray tightly cemented quartzitic siltstone that is more typical of the lower part of the Harkless Formation.

The siltstone member consists largely of a thick monotonous sequence of grayish-olive, pale-olive, and dark-greenish-gray fine siltstone or phyllitic siltstone composed of silt-sized quartz grains set in a matrix of chlorite, muscovite, and biotite. The rock probably has been at least slightly metamorphosed everywhere, and commonly is phyllitic siltstone, phyllite, or hornfels. The hornfels is composed of muscovite, biotite, chlorite, and quartz, and commonly the biotite and chlorite occur in ovoid aggregates about 0.5 to 1 mm across that give the rock a spotted appearance. Very thin beds of light-brown limestone occur in the siltstone member, probably mostly in the upper part, and those generally contain *Salterella,* an elongate conical fossil about a quarter of an inch long.

The thickness of the siltstone member is about 2,205 feet in measured section in the Weepah Hills (fig. 5), although some faults occur and the exact thickness of the member is somewhat uncertain.

The upper part of the siltstone member locally contains quartzite, sandy limestone, and limestone interstratified with siltstone and is lithologically similar and probably correlative with the Saline Valley Formation as defined by Nelson (1962, p. 142) in the White and Inyo Mountains, Calif. The Saline Valley Formation overlies the Harkless Formation and includes, in its type area, quartzite, quartzitic sandstone, sandy limestone, limestone, and gray-green and black shale (Nelson, 1962, p. 142). In Esmeralda County, however, as was first recognized by Nelson (1962, p. 142), the Saline Valley Formation is not well defined, and strata that have the same stratigraphic position as the Saline Valley Formation are largely, although not entirely, green siltstone lithologically resembling the Harkless Formation. The strata that do resemble the Saline Valley Formation in Esmeralda County have a spotty distribution and seemingly cannot be consistently mapped separately from the Harkless Formation. For these reasons, the term Harkless Formation is used in Esmeralda County to include strata laterally continuous with the Saline Valley Formation. Such a usage recognizes that the Harkless and Saline Valley Formations are virtually inseparable in Esmeralda County. For descriptive purposes, however, the term "Saline Valley equivalent" is retained to indicate those strata in the upper part of the Harkless Formation in Esmeralda County that are probably lithologically correlative to the type Saline Valley Formation of California.

Strata that most closely resemble the Saline Valley Formation occur in an area 6 to 7 miles northeast of Gold Point, near Alkali Spring, and along the crest of Paymaster Ridge from half a mile to 4 miles north of the Goldfield-Silver Peak road. At the locality northeast of Gold Point, 120 feet of strata resembling the Saline Valley Formation are exposed. Here the strata include pale-yellowish-brown and medium-gray, aphanitic to medium-crystalline lime-

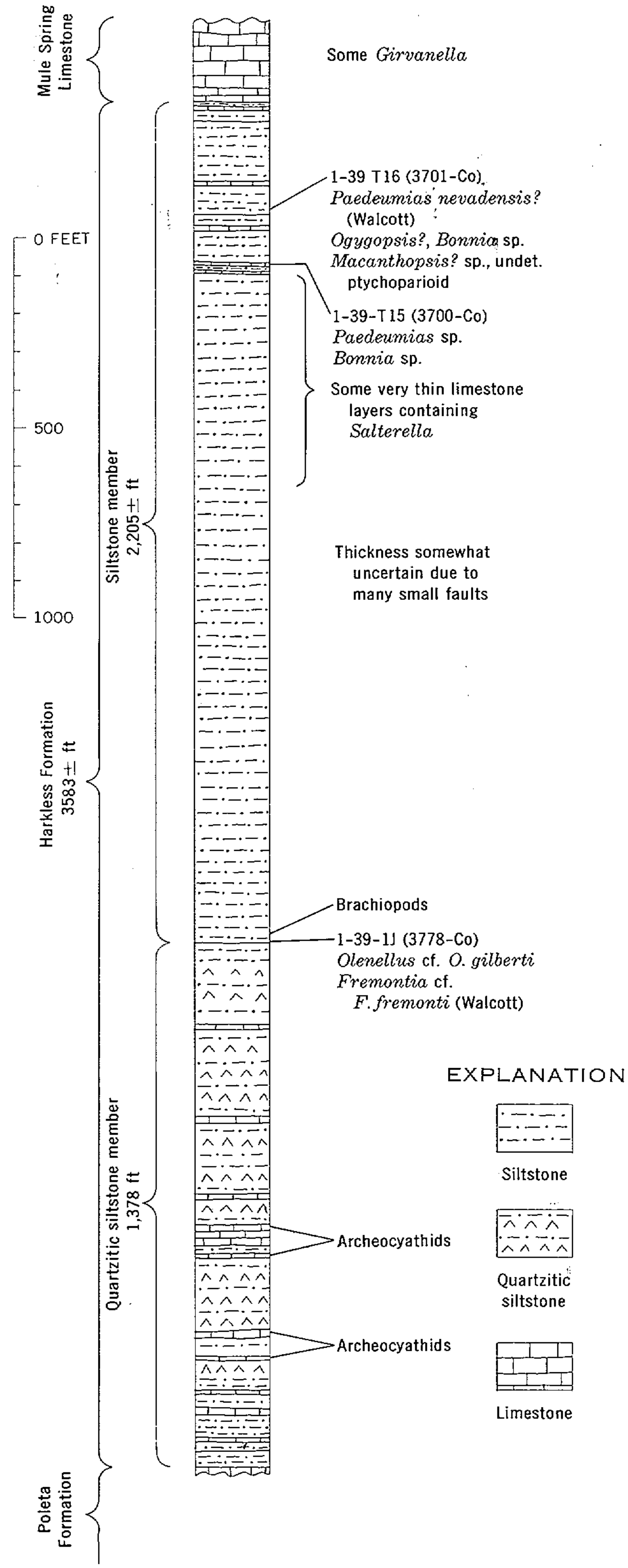

Figure 5. Columnar section of Harkless Formation in Weepah Hills, 1 to 2 miles west of Paymaster Canyon, 2 to 4 miles west of southern part of sec. 30, T. 1 N., R. 41 E.

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stone, minor amounts of limestone containing as much as 50 percent fine to coarse well-rounded quartz grains, and a 46-foot sandstone bed. The sandstone is pale yellowish brown, pale brown, and pale red, fine to medium grained with some coarse and very coarse grains, and weathers to form a prominent cuesta. The limestone at the base of this sequence contains pisolitic structures that may be *Girvanella*. The strata exposed at the localities near Alkali Spring and in the Paymaster Ridge are similar to that northeast of Gold Point, although more strata are exposed and may include a larger amount of limestone. The basal limestone unit of this sequence on Paymaster Ridge contains possible *Girvanella* similar to the sequence northeast of Gold Point.

The top 446 feet of the Harkless Formation in the Weepah Hills section contain five limestone beds from 4 to 7 feet thick, but no sandy limestone nor quartzite occurs in this section. This top part of the Harkless Formation may be equivalent to the Saline Valley Formation but except for the limestone does not lithologically resemble the Saline Valley Formation.

Quartzite that may be lithologically equivalent to the Saline Valley Formation occurs interstratified with siltstone on Mount Jackson Ridge northwest of Lida Junction, in the Goldfield Hills about 8 miles south of Goldfield, and in the Montezuma Peak area. The quartzite is pinkish gray and yellowish gray and is composed of fine to medium, rarely coarse, rounded to well-rounded quartz grains tightly cemented together by secondary overgrowths of quartz. On Mount Jackson Ridge, the quartzite occurs in several beds from a few inches to 65 feet thick over a stratigraphic interval of at least 330 feet. The quartzite constitutes about 30 percent of this 330 feet. *Scolithus* worm borings occur in the topmost quartzite. The occurrence of quartzite in the Goldfield Hills is similar to that in the Mount Jackson Range, but only one bed of quartzite, from 2 to 4 feet thick, occurs in the Montezuma Peak area. The stratigraphic position of these quartzite layers within the Harkless Formation is not certain, but they probably are in the upper part of that formation, and approximately equivalent to part of the Saline Valley Formation.

The trilobite *Ogygopsis* occurs in the strata of the Saline Valley equivalent in the area northeast of Gold Point (Palmer, 1964, p. F6–F7), in the area near Alkali Spring, and in strata near the top of the Weepah Hills section (see faunal list below). As has been indicated by Nelson (1963, p. 246), *Ogygopsis* characteristically occurs in the Saline Valley Formation in the White and Inyo Mountains, and the occurrence of this fossil in Esmeralda County supports the chronologic correlation of these strata with the Saline Valley Formation.

The fine- to medium-grained quartzite in possible Saline Valley equivalents in the county are considered to be northward-extending tongues of the Zabriskie Quartzite, a prominent and thick quartzite in areas to the south in southern Nye County, Nev., and eastern Inyo County, Calif. The quartzite of the Zabriskie is similar to that in the Harkless Formation, particularly those quartzites on Mount Jackson Ridge and in the Goldfield Hills, and all these quartzites characteristically contain *Scolithus* worm borings. As mentioned by Stewart (1966, p. C72), the quartzite in the Saline Valley Formation in its type area is also a tongue of the Zabriskie.

The total thickness of the Harkless Formation, including the Saline Valley equivalent, is about 3,583 feet in the Weepah Hills section (fig. 5). This is the only place in the county where the formation is continuously and completely exposed, and even here some faults occur and the exact thickness is uncertain.

The top contact of the Harkless Formation is placed at the change from greenish siltstone below to gray or brown *Girvanella*-bearing limestone of the Mule Spring Limestone above. Commonly the lower part of the Mule Spring Limestone consists of limestone and interbedded silty limestone and limy siltstone, and the contact is here placed at the base of the lowest well-defined limestone. In many parts of the county, the contact of the Harkless and Mule Spring Formations is a low-angle or flat fault that marks the change from the structurally weak siltstone of the Harkless Formation to the structurally competent limestone of the Mule Spring Limestone.

Distinguishing the Harkless Formation from the lithologically similar Campito Formation is difficult in many areas, particularly where the rocks have been metamorphosed near granitic contacts. The dark quartzite strata of the Andrews Mountain Member of the Campito Formation are very similar lithologically to the quartzitic siltstone of the Harkless Formation. Furthermore, the siltstone of the Montenegro Member of the Campito Formation is similar to the siltstone of the Harkless Formation. In some areas, the formations can be identified by the presence of distinctive fossils. In other areas, the mapping of overlying or underlying formations and the determination of the stratigraphic succession may indicate which formation is present. In structurally complex areas or in areas where the strata have been metamorphosed, however, distinguishing the Harkless from the Campito is uncertain. Considerable uncertainty exists about the identification of the Harkless Formation in the following areas: (a) a northwest-trending belt along the west side of the Silver Peak Mountains both to the south and north of Oasis Divide, (b) on the east side of the White Mountains, (c) on the west side of Clayton Ridge near the southern end of the range, (d) on the west side of the Montezuma Range near the southern end, and (e) on the east side of Lone Mountain. Strata in these outcrops have been assigned to the Harkless Formation, which they appear most closely to resemble, but further work may prove that the strata in some of these outcrops may actually belong to the Campito Formation.

A large number of fossil collections have been made in the Harkless Formation. These have been grouped into three different categories, which are: (A) collections with *Olenellus* cf. *O. gilberti* which may indicate a zone in the middle of the formation; (B) fossils from rocks in the upper part of the formation in part, at least, from strata equivalent to the Saline Valley Formation; and (C) collections with *Paedeumias nevadensis*. Group C occurs in about the top 200 feet of the Harkless Formation in strata equivalent in part to the Saline Valley Formation but apparently higher than group B.

In addition to the fossils listed below, Palmer (1964) has described an unusual and large fauna from strata probably equivalent to the Saline Valley Formation. This locality, 670–25J, was first discovered by the writers. The fossils were identified by A. R. Palmer.

Group A:

1–39–1J (USGS collection 3778–CO), sec. 26 (unsurveyed), T. 1 N., R. 40 E., 1,378 to 1,383 feet above base of Harkless Formation, Weepah Hills sections.
Olenellus cf. *O. gilberti* Meek
Fremontia cf. *F. fremonti* (Walcott)

1–49–13 (USGS collection 3780–CO), north-central part of sec. 22, T. 1 S., R. 38 E., stratigraphic assignment uncertain. Strata originally mapped as Poleta Formation, but may be in thrust plate of Harkless Formation.
Olenellus cf. *O. gilberti* Meek
Paedeumias? sp.

1–39–T2 (USGS collection 3779–CO), 2½ miles west of sec. 19, T. 1 N., R. 41 E., Harkless Formation, position within formation not determinable.
Olenellus cf. *O. gilberti* Meek
Paedeumias cf. *P. clarki* Resser
Fremontia sp.

1–51–48 (USGS collection 3783–CO), NW¼ sec. 10, T. 1 S., R. 37 E., Harkless Formation, position within formation uncertain, but may be in middle part.
Specimens that look like *Olenellus* not much different from *O. gilberti*.

Group B:

670–30J (USGS collection 3655–CO), near southwest corner sec. 22, T. 6 S., R. 42 E., upper part of Harkless Formation.
Bonnia caperata (Palmer)
Ogygopsis batis (Walcott)
Olenoides sp.
Paedeumias granulatus (Palmer)
Wanneria sp.
rugose helcionellid

670–34J (USGS collection 3659–CO), SW¼ sec. 16, T. 6 S., R. 42 E., upper part of Harkless Formation, similar stratigraphic position to 670–30J.
Bonnia
olenellid scraps
oryctocephalid
dolichometopid comparable with *Athabaskia*

3–54–6 (USGS collection 3496–CO), SE¼ sec. 3, T. 3 S., R. 41 E., upper part? of Harkless Formation.
Bonnia sp.
indeterminate olenellids

3–28–3 (USGS collection 3703–CO), east-central part of sec. 27, T. 1 S., R. 41 E., upper part of Harkless Formation.
Ogygopsis batis (Walcott)

3–20–5 (USGS collection 3489–CO), south-central part of sec. 10, T. 2 S., R. 38 E., upper part(?) of Harkless Formation.
Olenellids, scraps in insoluble residue have reticulated ornament
Bonnia sp.
numerous small gastropods? referable to *Pelagiella*
scraps of the phosphatic brachiopod *Paterina*

1–39–T16 (USGS collection 3701–CO), sec. 25 (unsurveyed), T. 1 N., R. 40 E., 216 to 289 feet below top of Harkless Formation, Weepah Hills section.
Paedeumias nevadensis? (Walcott)
Ogygopsis?
Bonnia sp.
Macanthopsis? sp.
undet. ptychoparioid.

1–39–T15 (3700–CO), sec. 25 (unsurveyed), T. 1 N., R. 40 E., 322 feet below top of Harkless Formation, Weepah Hills section.
Paedeumias sp.
Bonnia sp.

3–20–6 (USGS collection 3573–CO), west-central part of sec. 10, T. 2 S., R. 38 E., probably upper part of Harkless Formation.
A form referable to *Olenellus*

1–41–10J (USGS collection 3572–CO), near southwest cor. sec. 7, T. 1 N., R. 41 E., near top(?) of Harkless Formation.
A form referable to *Olenellus*

2–3–14 (USGS collection 3571–CO), SE¼ sec. 7, T. 4 S., R. 41 E., near top of Harkless Formation.
A form referable to *Olenellus*

1–13–25J (USGS collection 4129–CO), SE¼ sec. 35, T. 2 N., R. 35 E., position in Harkless Formation not determinable.
Specimens of *Paedeumias*

23B (USGS collection 3499–CO), NW¼ sec. 2, T. 4 S., R. 42 E., probably upper part of Harkless Formation.
Paedeumias sp.
Crassifimbra? sp.
slender archaeocyathids

667–13J (3705–CO), southeast part sec. 33, T. 4 S., R. 42 E., 28 to 38 feet below top of Harkless Formation. Top of Harkless could be faulted. Goldfield Hills section.
Paedeumias sp.

Group C:

2–3–42 (USGS collection 3566–CO), ½ mile west of western corner between secs. 18 and 19, T. 4 S., R. 41 E., near top of Harkless Formation.
Paedeumias nevadensis (Walcott)

1–51–T3 (USGS collection 3781–CO), east-central part sec. 19, T. 1 S., R. 38 E., about 100 feet below top of Harkless Formation.
Paedeumias nevadensis (Walcott)
undet. ptychoparioid

1–129–109 (USGS collection 3569–CO), 1¼ miles west of sec. 19, T. 4 S., R. 41 E., upper part of Harkless Formation.
Paedeumias nevadensis (Walcott)
665–72J (USGS collection 3570–CO), central part sec. 28, T. 4 S., R. 42 E., probably upper part of Harkless Formation.
Paedeumias nevadensis (Walcott)
1–41–8J (USGS collection 3576–CO), near western corner between secs. 7 and 18, T. 1 N., R. 41 E., upper part of Harkless Formation.
Paedeumias nevadensis (Walcott)

Mule Spring Limestone

The Mule Spring Limestone is the youngest formation of Early Cambrian Age in the county. It crops out (1) in a small area 6 miles northeast of Gold Point, (2) on Mount Jackson Ridge, (3) in the Goldfield Hills, (4) near Lida and in the Palmetto Mountains, (5) on the south side of Clayton Valley, (6) in the Silver Peak Mountains northwest of Mineral Ridge, (7) in the Montezuma Range, (8) on Clayton Ridge, (9) on the northern part of Paymaster Ridge, (10) in the Weepah Hills, particularly west of Paymaster Canyon, (11) in the General Thomas Hills, and (12) the South Klondike mining area. A marble possibly correlative to the Mule Spring Limestone occurs on Miller Mountain (see description of stratigraphy on Miller Mountain under separate heading).

The Mule Spring Limestone consists of medium-gray to medium-light-gray very finely to finely crystalline, locally aphanitic limestone characteristically containing concretionary algal structures *(Girvanella)* that range in size from ½ to 1 inch in diameter. The amount of *Girvanella* in the formation is quite variable. In some beds these structures are absent, in other beds they occur as a few scattered individuals, and in still other beds they are abundant and constitute as much as 40 percent of the rock. The gray colors of the limestone are commonly patchy or mottled. The limestone is very thin to thin bedded in most places, although structureless parts occur locally.

Beds of limy siltstone and silty limestone occur commonly in the lower 100 to 150 feet of the formation. These beds range in thickness from a few feet to about 50 feet and are conspicuous on outcrops on Mount Jackson Ridge west of Lida Junction, on the northern part of Clayton Ridge, and on the northern part of the Paymaster Ridge. However, in other places such as in the Weepah Hills section (fig. 5) and in the Goldfield Hills section (fig. 6) these silty beds appear to be absent from the lower part of the formation. The characteristic color of the limy siltstone and silty limestone is pale yellowish brown and the clastic fraction is coarse silt to very fine sand. The limestone associated with the silty layers commonly is grayish orange, although the typical gray colors also occur.

The thickness of the Mule Spring Limestone is apparently about 400 to 500 feet, although a complete and demonstrably unfaulted section has not been measured in the county. A thickness of 450 feet was measured in an unfaulted but incomplete section of the formation on the northern part of Paymaster Ridge. The total thickness of the formation here could be as much as 800 feet. A thickness of 246 feet was measured in a seemingly complete section of the formation in the Goldfield Hills 12 miles south of Goldfield, although the base of the formation here could be a fault. In any case this thickness of 246 feet seems too thin.

The contact between the Mule Spring Limestone and overlying Emigrant Formation is sharp and marks a change from *Girvanella*-bearing limestone below to siltstone directly above the contact. The lower part of the Emigrant Formation consists of interbedded limestone, siliceous limestone, and siltstone and is sharply contrasted with the underlying continuous limestone of the Mule Spring Formation. The contact is well exposed in the Goldfield Hills, on Paymaster Ridge, and in the Weepah Hills sections (fig. 6).

Four fossil collections were made from the Mule Spring Limestone in Esmeralda County. All but one of the collections are from the lower somewhat silty part of the formation. The fourth collection (MS1–5–239) is from 216 feet above the base of the Mule Spring Limestone and about 60 feet above the highest silty bed in the formation in that area. The fossils were identified by A. R. Palmer, except for part of the collection from 3–52–5 which was identified by C. A. Nelson.

667–16J (USGS collection 3654–CO), SW¼ sec. 12, T. 5 S., R. 42 E.
Possibly *"Wannerina"* sp.
667–36J (USGS collection 4130–CO), central part sec. 23, T. 5 S., R. 42 E.
Bristolia "bovis"
Paedeumias sp.
an undeterminable ptychoparioid
3–52–5 (USGS collection 3560–CO), near western corner between secs. 30 and 31, T. 2 S., R. 41 E.
Collection made by J. P. Albers and identified by A. R. Palmer.
Bristolia sp.
Fremontia sp.
Bonnia sp.
a mollusk, probably *Helcionella*
Collected and identified by C. A. Nelson.
Olenellus gilberti
Bonnia sp.
MS1–5–239 (USGS collection 3565–CO), 1¼ miles west of sec. 6, T. 1 S., R. 41 E.
Antagmus?
Fremontia
a mollusk possibly referable to *Scenella*

MIDDLE AND UPPER CAMBRIAN STRATA

Emigrant Formation

The Emigrant Formation was named by Turner (1902, p. 265) for exposures near Emigrant Pass in Esmeralda County. The stratigraphy of the lower 1,500 to 2,000 feet

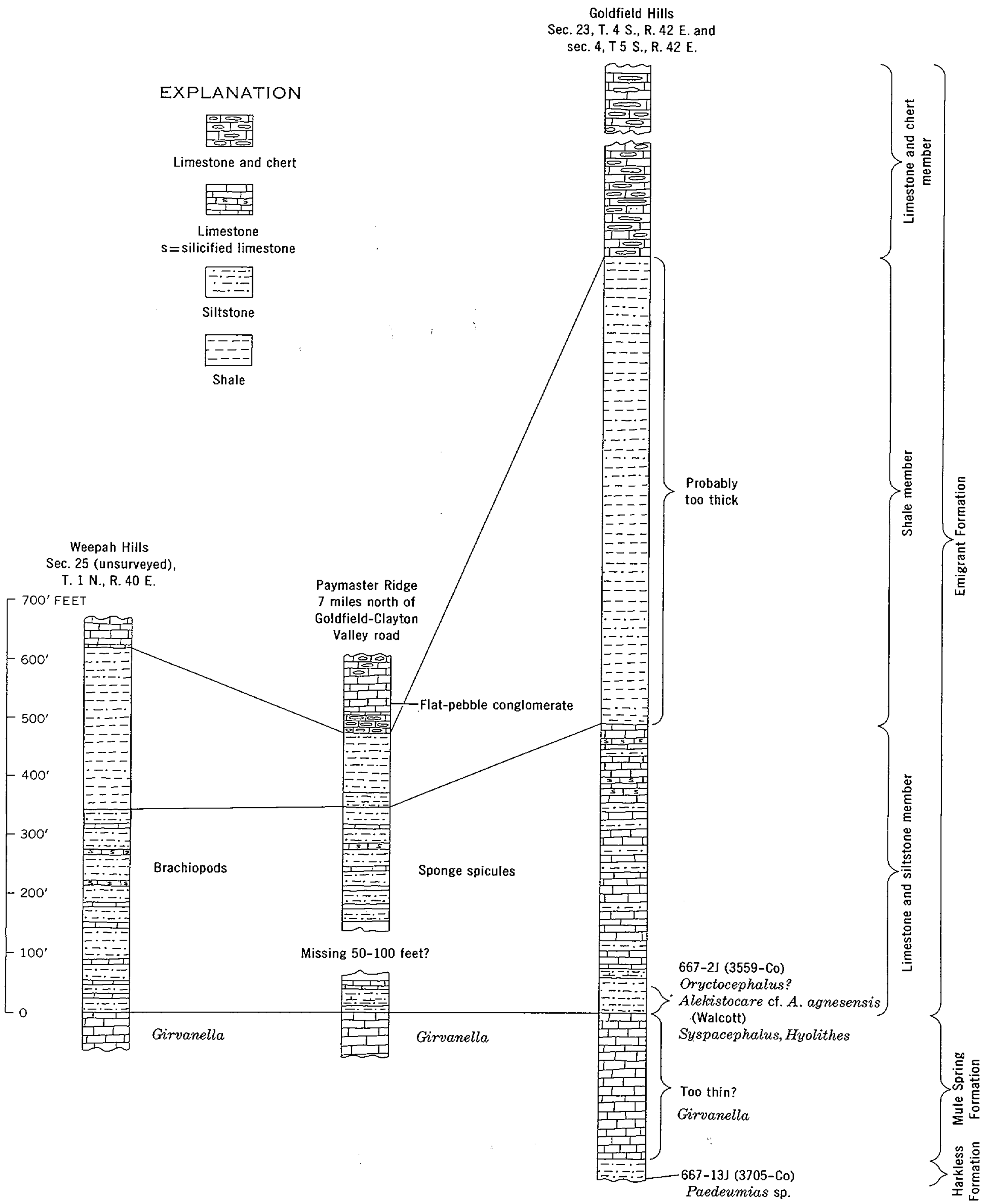

Figure 6. Correlation of part of Emigrant Formation.

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of the formation is well known from outcrops in several parts of the county, but the sequence of units and thickness of the remainder of the formation is uncertain owing to complex structure and lack of key beds.

The Emigrant Formation crops out in the following areas: (1) south, northeast, and northwest of the Palmetto Mountain, (2) Mount Jackson Ridge, (3) Goldfield Hills, (4) southern end of the Montezuma Range, (5) locally on Clayton Ridge, (6) Angel Island in Clayton Valley, (7) north end of Paymaster Ridge, (8) General Thomas Hills, (9) Weepah Hills, (10) South Klondike mining area, and (11) Emigrant Pass area.

The Emigrant Formation is divided into three members named informally from bottom to top, the limestone and siltstone member, the shale member, and the limestone and chert member.

The limestone and siltstone member consists of closely interlayered beds of medium-gray aphanitic to very finely crystalline limestone, light-gray, pale-red, and pale-red-purple papery-fine siltstone, and minor amounts of medium-gray thinly laminated silicified limestone. Sponge spicules and phosphatic brachiopod shells occur locally in the siltstone. The basal part of the member in the Goldfield Hills and on Clayton Ridge is a unit of olive-gray siltstone to claystone about 60 feet thick that is locally highly fossiliferous (see faunal list below for 667−2J and 2−3−45). The amount of limestone in the member decreases to the north from about 60 percent in the Goldfield Hills section to about 30 percent in the Paymaster Canyon section (fig. 6).

The limestone and siltstone member is 492 feet thick in the Goldfield Hills section, 344 feet thick in the Weepah Hills section, and about 300 to 350 feet thick in the Paymaster Ridge section (fig. 6).

The shale member is a monotonous sequence of olive-gray to greenish-gray very thinly laminated shale. Locally a moderate-yellowish-brown color develops along fractures and cleavage planes in the shale; the unit itself weathers moderate yellowish brown in some places. The shale member can be confused, from a distance, with green siltstone of the Harkless Formation or of the Montenegro Member of the Campito Formation, but on close examination the grain size of the shale is distinctly finer than that of the Harkless or Montenegro siltstones. The measured thicknesses of the shale member are: in the Goldfield Hills, about 800 feet; on Paymaster Ridge, 126 feet; and in the Weepah Hills, 244 feet. Much of this variation in thickness is probably caused by structural movement in the incompetent shale of the member that increases the apparent thickness of the member in some areas and decreases it in other areas. An average figure for the thickness of the member may be about 300 feet.

The limestone and chert member consists dominantly of thinly interlayered beds of limestone and chert. Individual outcrops of this lithologic type locally cover several square miles. The limestone is medium gray, aphanitic, and occurs in beds from ½ to 3 inches thick interstratified with the chert. The chert is medium gray, although it commonly weathers dark yellowish brown, is evenly laminated, and occurs as ⅛- to 1-inch layers or broad lens-shaped masses interstratified with the limestone. The chert constitutes about 20 percent of the strata, but locally the percentage is higher. The chert commonly grades laterally into limestone and is probably mostly of replacement origin. Locally as much as 100 feet of noncherty limestone occur at the base of, or within, the limestone and chert sequence of the upper part of the formation. A few thin layers of intraformational flat-pebble conglomerate commonly occur in the limestone and chert sequence. These layers consist of disc-shaped pieces of limestone, as large as 3 inches in diameter, set in a calcite matrix. The limestone and chert member reacts incompetently to deformation stress and is commonly tightly folded on a small scale. Generally the distance between adjacent fold axes along a bedding plane is about 1 to 10 feet.

In some areas the limestone and chert member of the Emigrant Formation contains thick units of (1) interlayered aphanitic to very finely crystalline limestone, clastic limestone, siltstone, and, locally, chert; (2) interlayered limestone and siltstone, and (3) claystone. Units containing limestone, clastic limestone, siltstone, and, locally, chert occur in the Emigrant Pass area, the northern part of Paymaster Ridge, and in the southwestern part of the General Thomas Hills. In the Emigrant Pass area, these strata are at least 300 feet thick and consist of light-brown, yellowish-brown, and pale-red siltstone, medium-gray and moderate-red aphanitic to very finely crystalline limestone, and pale-red to light-brownish-gray clastic limestone. The clastic limestone contains red siltstone fragments and very fine grains of quartz. Medium-gray and pale-red chert also occurs locally. These strata lie above a flat or low-angle fault, and the red color may be due to chemical alteration along this fault. The limestone and clastic limestone constitute about 25 percent of this sequence, and the rest is siltstone with a small amount of chert.

Units of interlayered limestone, clastic limestone, and siltstone on Paymaster Ridge and in the southwest part of the General Thomas Hills are similar to that in the Emigrant Pass area, although the amount of limestone is greater, generally totaling about 50 percent, and the strata are not red. In these areas also, the limestone appears to be composed of clastic grains of carbonate minerals, but no fragments of siltstone or grains of quartz were noted. In the northern part of Paymaster Ridge, the clastic limestone locally is cross-stratified on a minute scale, and these cross-strata may be cross sections of ripple marks. Flat-pebble conglomerate containing fragments of limestone also occurs in the northern part of Paymaster Ridge.

The position of the limestone-clastic limestone-siltstone units within the upper part of the Emigrant Formation is uncertain. Fossils from this lithologic type in the Emigrant Pass area (1−32−14, 1−32−5, and USGS collection 1602−CO, see faunal lists below) contain, among other fossils, inarticulate brachiopods including a specimen that looks like a *Pegmatreta*. This fossil indicates a Middle Cambrian Age although this dating needs checking (A. R. Palmer, written communication, 1963). If this date is correct, the limestone-clastic limestone-siltstone unit in the Emigrant Pass area and its possible correlatives on Paymaster Ridge and in the General Thomas Hills may occur low in the limestone and chert member of the Emigrant Formation. On the other hand, this lithologic type does not appear to be the lowest one in the member as limestone and chert occur at the base of the member in the Goldfield Hills, Paymaster Ridge, and Weepah Hills sections (fig. 6).

In some areas, yellowish-brown, greenish-gray, pale-red, pale-red-purple, or light-gray siltstone occurs interstratified with limestone of the limestone and chert member of the Emigrant Formation. The limestone associated with the siltstone is generally noncherty and does not contain clastic layers. Such units of siltstone and limestone occur in what has been mapped as the top few hundred feet of Emigrant Formation in the southernmost part of the Montezuma Range, in the Goldfield Hills 9 miles south of Goldfield, on Angel Island in Clayton Valley, and about 2 miles south of Emigrant Pass. However, as will be discussed later, the top of the Emigrant Formation is uncertain in some places, and the strata at some of these localities may not be in the top part of the Emigrant Formation. In addition, similar strata occur in what appears to be near the base of the limestone and chert member in the east-central part of the Weepah Hills directly west of Paymaster Canyon.

Thick units of claystone, lithologically similar to that in the shale member of the Emigrant Formation, may also occur within the limestone and chert members. These claystone units occur in structurally complex areas and their exact stratigraphic assignment is uncertain. Some, or perhaps all, could be actually the shale member itself. Differentiation of more than one claystone unit in the Emigrant Formation, if more than one exists, will depend on further work.

The thickness of the limestone and chert member of the Emigrant Formation is uncertain. In the Goldfield Hills section the lower 610 feet of the member, consisting of thinly interlayered limestone and chert, were measured in an unbroken sequence. The total thickness of the member, however, probably is considerably thicker than this 610 feet judging from the amount of outcrop of this type of strata.

The thickness of strata of Middle and Late Cambrian Age, the age span of the Emigrant Formation (see faunal lists below), in regions near Esmeralda County is from 5,000 to over 6,000 feet. Strata of this age in the Independence quadrangle in the Inyo Mountains about 40 miles to the southwest of Esmeralda County are about 5,300 feet thick (D. C. Ross, oral communication, 1963) and over 6,000 feet thick on Bare Mountain 25 miles southeast of the southern tip of Esmeralda County (Cornwall and Kleinhampl, 1961). From a regional viewpoint, the thickness of the Emigrant Formation should be of about the same general thickness as rocks of comparable age in adjoining area. The formation, therefore, may be about 5,000 to 6,000 feet thick and, if the lower two members are considered to total about 700 feet in thickness, the limestone and chert member would be from 4,000 to 5,000 feet thick.

The upper contact of the Emigrant Formation is placed at the change from limestone and siltstone, or locally from interlayered limestone and chert, of the Emigrant Formation, to the varicolored shale of the overlying Palmetto Formation of Ordovician Age. The lowermost strata of the Palmetto commonly contain *Caryocaris* (a crustacean) and graptolites. As will be discussed later, however, the Palmetto Formation probably contains, at least locally, units of limestone and chert and of limestone and siltstone that resemble those in the Emigrant Formation. Some units that are placed in the Emigrant Formation could therefore have been misidentified.

Fossils are not abundant in the Emigrant Formation, but range in age from earliest Middle Cambrian to latest Late Cambrian. The Middle Cambrian, however, except for the oldest part, is represented by only a few fossils of questionable age. The Upper Cambrian is represented by fossils from both the Franconian and Trempealeauan Stages. The fossils have been identified by A. R. Palmer, except for 665–67J, 665–66J, and 665–61J, which were identified by R. J. Ross, Jr.

Group A, lowermost Emigrant Formation, basal unit of limestone and siltstone member:

667–2J (USGS collection 3559–CO), SW¼ sec. 33, T. 4 S., R. 42 E., basal 47 feet of Emigrant Formation, Goldfield Hills section.

Oryctocephalus?
Alokistocare cf. *A. agnesensis* (Walcott)
Syspacephalus
Hyolithes
Age: contains trilobites of the *Wenchemia-Stephenaspis* fauna, the oldest Middle Cambrian fauna.

2–3–45 (USGS collection 3556–CO and 3650–CO), ¾ miles west of sec. 19, T. 4 S., R. 41 E., lowermost Emigrant Formation, stratigraphic position comparable to 667–2J above.

Indeterminate simple ptychoparioid trilobites of Middle Cambrian type, most likely either early or middle Middle Cambrian.

Group B, questionable Middle Cambrian, limestone and chert member:

1–32–14 (USGS collection 3487–CO and 3746–CO), south-central part sec. 29 (unsurveyed), T. 1 N., R. 37 E.

Several individuals of a form related to *Molaria* or *Emeraldella*, nontrilobitic arthropods known previously only from the Burgess Shale of British Columbia.

1–32–5 (USGS collection 3485–CO), south-central part sec. 28 (unsurveyed), T. 1 N., R. 37 E.

Indeterminate dorypygiid trilobite on thin limestone slab. More massive piece of limestone yielded abundant *Chancelloria* spicules and undescribed humpbacked pegmatretid brachiopods.
Age: Questionably Middle Cambrian, the trilobites, the particular kind of *Chancelloria* spicules, and the pegmatretid brachiopods are all suggestive of a Middle Cambrian Age, although the collection could be unusual Lower Cambrian

fauna such as that described by Palmer (1964) near Gold Point.

USGS collection 1602–CO, about same locality as 1–32–5 above. Collected by A. R. Palmer

Collection contains primarily brachiopods, one of which is referable to the genus *Dictyonina* and another belongs to an undetermined acrotretid genus. Contains a few inarticulate brachiopods including a specimen that looks like *Pegmatreta*. This would indicate an age of Middle Cambrian for the sample.

Group C, Upper Cambrian, limestone and chert member:

3–52–95 (USGS collection 3557–CO), ½ mile west of sec. 6, T. 3 S., R. 41 E.

Richardsonella
Drumaspis
Homagnostus
Idahoia?
Pseudagnostus

Age: Assemblage assignable to the *Ptychaspis-Prossukia* zone of the middle Upper Cambrian (Franconian).

1–32–38 (USGS collection 3699–CO), NE¼ sec. 33 (unsurveyed), T. 1 N., R. 37 E.

Euptychaspis sp.
Tostonia? sp.
Saukiella sp.
Pseudagnostus sp.
Geragnostus sp.
Pareuloma? sp.
Bienvillia sp.
Apatokephalus sp.
Idiomesus sp.
Zacompsus cf. *Z. clarki* Raymond
"Acidaspis" cf. *"A." ulrichi* Bassler
4 undetermined genera
eurekiid

Age: Forms characteristic of uppermost Upper Cambrian over much of the Great Basin. Trempealeauan Stage.

1–32–19 (USGS collection 3555–CO), central part sec. 33 (unsurveyed), T. 1 N., R. 37 E.

Euptychaspis
Eurekia?

Age: Forms characteristic of uppermost Upper Cambrian at Eureka, Nev., and other localities in central and eastern Nevada. Trempealeauan Stage.

665–67J (USGS collection D769–CO), SW¼ sec. 22, T. 4 S., R. 42 E.

Caryocaris? sp.
Meristome? fragments
Very problematical

665–66J (USGS collection D768–CO), SW¼ sec. 22, T. 4 S., R. 42 E.

Dictyonema sp.
indeterminate trilobites

Age: *Dictyonema* ranges from Late Cambrian to Mississippian.

665–61J (USGS collection D767–CO), SW¼ sec. 22, T. 4 S., R. 42 E.

Dictyonema sp.
Sponge spicules
inarticulate brachiopod

Age: *Dictyonema* ranges from Late Cambrian to Mississippian.

PRECAMBRIAN AND CAMBRIAN STRATA IN MILLER MOUNTAIN AREA

Five units of Precambrian and Cambrian Age have been mapped in the Miller Mountain area in the northwestern part of the county. One of these (the Campito Formation) can be correlated with confidence with strata in the rest of the county, but the stratigraphic assignment of the other four is uncertain. The strata on Miller Mountain were originally studied by Ferguson and Muller (1949, p. 45) and subsequently named the Miller Mountain Formation (Early Cambrian) by Ferguson and others (1954). The area has been described by Ross (1961, p. 11–12) and was studied in detail by Wilson (1961) who mapped five formations, all previously included in the Miller Mountain Formation. This report recognizes the same five formations, although the stratigraphic assignments and names used here differ somewhat from that of Wilson. The name Miller Mountain Formation is therefore considered abandoned.

The Campito Formation, the oldest formation exposed in the area, crops out in a broad east-trending band on the south side of Miller Mountain. Its base is not exposed, and the minimum exposed thickness is 1,800 feet (Wilson, 1961, p. 15). The Campito consists of black to dark-gray, commonly brown-weathering, siliceous hornfels that is laminated to massive bedded. The formation is thinner bedded in the upper part although the shaly Montenegro Member, the upper member of the Campito elsewhere in the county, cannnot be recognized. Trilobites, similar to those in the Campito Formation elsewhere, occur in the top 50 feet of the formation (Wilson, 1961, p. 17; C. A. Nelson, written communication, 1962).

Conformably overlying the Campito Formation is a 625-foot unit of metamorphosed clastic and carbonate rocks (Wilson, 1961, p. 22–24) that are lithologically and faunally similar to the Poleta Formation. The sequence of subunits, however, is only roughly similar to that in the Poleta, and use of the name Poleta on Miller Mountain is therefore uncertain. The questionable Poleta consists of dark-brown to black siliceous hornfels, yellow-brown and greenish-gray calc-silicate hornfels, and gray massive marble and dolomitic marble. The calc-silicate hornfels and the marble commonly occur in thin layers interstratified with the siliceous hornfels, although marble layers from several tens of feet to as much as 100 feet in thickness also occur. Among the fairly abundant fossils in the formation (Wilson, 1961, p. 31) is the trilobite *Nevadella*, a form common in the Poleta Formation.

In the easternmost part of the Miller Mountain area, including exposures in roadcuts on U.S. Highway 6, is a unit of dark-brown to black siliceous hornfels, light-green calc-silicate hornfels, gray and yellow-brown marble, and dolomitic marble. Assignment of these rocks to any known formation is uncertain. Wilson (1961, p. 12–14) considered that they were part of the Deep Spring Formation, a formation stratigraphically underlying the Campito, but we think that they may be correlative with the higher Harkless Formation. They are shown as questionable Harkless on the map.

A 607-foot unit of light-gray massive marble occurs near the county line in the Miller Mountain area (Wilson, 1961, p. 32). The upper 20 feet contain Lower Cambrian trilobites in a laminated hornfels and marble sequence (Wilson, 1961, p. 35). The unit is everywhere in fault contact with stratigraphically underlying units and lies conformably below a unit composed dominantly of phyllite and hornfels. The marble is lithologically similar to the Mule Spring Limestone and is tentatively correlated with that formation.

The highest exposed strata in the Miller Mountain area consist of at least 1,000 feet of brownish-gray to dark-greenish-gray phyllite and spotted siliceous hornfels (Wilson, 1961, p. 38–40). The basal 35 feet of this unit contain abundant trilobites including *Ogygopsis* and *Paedeumias* (Wilson, 1961, p. 40–41). The presence of olenellid-type trilobites indicates an Early Cambrian Age.

The correlation of this highest unit with strata exposed elsewhere in the county is uncertain. Its occurrence above a possible correlative of the Mule Spring Limestone suggests that it should be a part of the Emigrant Formation, a formation normally above the Mule Spring. The lithologic character of the unit on Miller Mountain, however, is not similar to that of the Emigrant and, furthermore, at least the basal part of the unit on Miller Mountain is Early Cambrian in age, whereas the basal part of the Emigrant is Middle Cambrian in age. These ambiguities cannot be reconciled at this time.

ORDOVICIAN STRATA

Palmetto Formation

The name Palmetto Formation was proposed by Turner (1902, p. 265) for outcrops in the Palmetto Mountains in Esmeralda County. The formation, as far as is known, is entirely of Ordovician Age and is the only formation of that age in the county except for strata in the Grapevine Mountains in the southernmost part of the county that have a different lithologic character (see discussion of stratigraphy in Grapevine Mountains under separate heading).

The Palmetto Formation crops out extensively in the county and in some areas forms broad belts covering many square miles.

The Palmetto Formation is composed dominantly of shale and siltstone. Locally these strata are metamorphosed to hornfels. The color of the rocks is varied and includes greenish gray, light greenish gray, light brown, pale red, pale red purple, pale yellowish brown, yellowish gray, grayish orange, light gray to medium dark gray, and black. The variety of these colors and the presence of light shades of green, red, and purple and, in some areas, of thick units with a black or dark-gray color are characteristic of the formation. Most of the shale, siltstone, and hornfels, are evenly and thinly laminated, commonly on a very fine scale. Graptolite remains are locally abundant in the shale, and *Caryocaris,* a crustacean, is commonly associated with the graptolites, although it also occurs in layers by itself. In some places the graptolites seem as abundant in the hornfels as in the less metamorphosed strata.

In most areas, units of chert, limestone, and interlayered limestone and chert are interstratified with the shale and siltstone. These lithologic types generally constitute less than 20 percent of the stratigraphic sequence, but locally they are more abundant. The chert is black and evenly laminated. It occurs mostly in layers from 1 to 10 feet thick. Limestone occurs in layers from a few inches to over 100 feet thick. It is medium gray to medium light gray and aphanitic to very finely crystalline. Interlayered limestone and chert occur in units from about 10 feet to probably over 200 feet thick. Some of these limestone and chert layers are identical to those in the Emigrant Formation; others have a higher percentage of chert (commonly 50 percent or over) than those in the Emigrant Formation. In addition, the chert is evenly and distinctly laminated whereas the chert in the Emigrant Formation does not have well-defined lamination. A 210-foot unit of interlayered limestone and chert, included in the Palmetto Formation, occurs about 1 mile north of Oasis Divide along the road between Silver Peak and Oasis. This unit is very similar to limestone and chert in the Emigrant Formation, but a close association with Palmetto-like strata seems to force its assignment to the Palmetto.

Quartzite layers occur in the lower part of the Palmetto Formation, probably mostly in the basal 500 feet. The quartzite is light brown to pale yellowish brown, fine grained, and occurs in units from about 5 to 20 feet thick interstratified with shale and siltstone. The quartzite is composed of rounded to well-rounded quartz grains that are tightly cemented by quartz overgrowths.

In the southernmost part of the Montezuma Range, the sequence of units in the lowermost part of the Palmetto Formation is as follows: (1) a 300-foot unit of shale and siltstone locally containing graptolites and *Caryocaris,* (2) a 200-foot unit of siltstone and shale containing quartzite layers from 5 to 20 feet thick, and (3) a 125-foot unit containing about equal amounts of interlayered medium-dark-gray limestone and black chert. The latter unit weathers to a dark-gray, almost black color. The thicknesses of these units have been estimated, and because the area is somewhat faulted some uncertainty exists about the exact thicknesses and sequences of units. In the southernmost part of the General Thomas Hills, a limestone and chert unit that is lithologically similar to the 125-foot unit of the southern Montezuma Range area, occurs in the lower part of the Palmetto Formation. The limestone and chert unit in these two areas may be the same. No quartzite, however, occurs below the limestone and chert unit in the General Thomas Hills.

The thickness of the Palmetto Formation and the sequence of units within the formation, except for the lowermost part, is not known because the formation is everywhere highly folded and faulted, and key beds have not been recognized that would help unravel the structure.

Judging from the large area of outcrop, the formation must be several thousand feet thick.

The following collections were made by the writers from the Palmetto Formation in the county. Some collections made previously by other geologists already have been reported on by Ross and Berry (1963, p. 22–24). All of the collections are of Middle Ordovician Age, except for NK–18 which is Early Ordovician, 1–2–19 which possibly is Early Ordovician, and 2–10–15 which is Late Ordovician. The age designations given below follow those used by Ross and Berry (1963). The identifications are by R. J. Ross, Jr.

NK–18 (USGS collection D1630–CO), NE¼ sec. 35, T. 2 S., R. 42 E.
- *Bryograptus?* sp.
- *Clonograptus* sp.
- Age: Early Ordovician

1–2–19 (USGS collection D766–CO), ¼ mile west of SW¼ sec. 18, T. 1 N., R. 41 E.
- *Phyllograptus* 2 spp.
- *Tetragraptus* aff. *T. serra* Brogniart
- *Tetragraptus* cf. *T. bigsbyi* (Hall)
- Age: Arenig to Llanvirn

1–129–26 (USGS collection D158–SD), SW¼ sec. 30, T. 4 S., R. 41 E.
- Includes very poor specimens of *Cardiograptus?* sp., *Isograptus caduceus* var., and *Glyptograptus* or *Amplexograptus*
- Age: Llanvirn to Llandeilo

1–129–29 (USGS collection D689–CO), 1 mile west of sec. 31, T. 4 S., R. 41 E.
- *Glyptograptus* sp.
- Fragments of uniserial stipes without virgula and probably *Didymograptus*
- Age: Ranges of these two genera overlap in late Llanvirn to early Caradoc. Zones 7–10 of Elles and Wood.

1–129–28 (USGS collection D690–CO), ½ mile west of sec. 31, T. 4 S., R. 41 E.
- *Climacograptus scharenbergi* Lapworth
- *Glyptograptus?* sp.
- Age: Llanvirn to middle Caradoc.

1–2–17 (USGS collection D764–CO), SW¼ sec. 18, T. 1 N., R. 41 E.
- *Glyptograptus teretiusculus* (Hisinger)
- *Amplexograptus* sp.
- *Orthograptus* sp.
- *Glyptograptus* sp.
- Age: Llandeilo to early Caradoc. Zones 8–10 of Elles and Wood.

1–129–24 (USGS collection D691–CO), SW¼ sec. 30, T. 4 S., R. 41 E.
- Includes fragmentary specimens of dichograptid type as well as poor specimens possibly referable to *Orthograptus* and *Glyptograptus*
- Age: Probably Middle Ordovician (Llandeilo to early Caradoc). However, additional material is needed to be sure of this dating.

1–11–12J (USGS collection D1021–CO), north-central part sec. 3 (unsurveyed), T. 1 N., R. 36 E.
- *Glyptograptus euglyphus* (Lapworth)
- *Diplograptus* sp.
- *Climacograptus* aff. *tubuliferous* Lapworth
- *Climacograptus* sp.
- *Dicellograptus sextans* Hall
- *Dicellograptus* or *Dicranograptus* sp.
- Age: Probably zone 9 of Elles and Wood, but could be zone 10.

El–B (USGS collection D683–CO), north-central part sec. 25, T. 4 S., R. 40 E.
- Graptolites:
  - *Dicellograptus* cf. *D. sextans* Hall
  - *Dicranograptus tealei* Harris and Thomas
  - *Retiograptus* sp.
  - *Glyptograptus?* sp.
- Conodont
- Age: Zones 9–10 of Elles and Wood.

1–10–T17 (USGS collection D1020–CO), north-central part sec. 36, T. 2 N., R. 36 E.
- *Climacograptus bicornis* Hall
- *Climacograptus* sp.
- Age: Zone 10 of Elles and Wood.

El–A (USGS collection D682–CO), north-central part sec. 36, T. 4 S., R. 40 E.
- Graptolites:
  - *Orthograptus* cf. *O. whitfieldi* (J. Hall)
  - *Orthograptus* sp.
  - *?Climacograptus* cf. *C. phyllophorus* (Gurley)
- Crustacea:
  - *Caryocaris* sp.
- Age: Zone 10 of Elles and Wood.

I–38 (USGS collection D684–CO), north-central part sec. 18, T. 1 N., R. 41 E.
- *Climacograptus bicornis* Hall
- *Glyptograptus?* sp.
- Age: Zone 10 of Elles and Wood.

2–10–33J (USGS collection D1105–CO), SW¼ sec. 17, T. 4 S., R. 38 E.
- *Glossograptus horridus* Ruedemann
- *Dicellograptus sextans* Hall
- *Glyptograptus teretiusculus* (Hisinger)
- *Glyptograptus* sp.
- *Climacograptus* sp.
- Age: Zone 10 of Elles and Wood.

2–10–25 (USGS collection D1104–CO), south-central part sec. 8, T. 4 S., R. 38 E.
- Fragment, possibly of *Didymograptus*
- *Dicranograptus nicholsoni* var. *whitianus* (Miller)
- *Dicellograptus* sp.
- *Glyptograptus* sp.
- Age: Zone 10 of Elles and Wood.

1–2–18 (USGS collection D765–CO), ⅛ mile west

of SW¼ sec. 18, T. 1 N., R. 41 E.
Graptolites:
Climacograptus bicornis Hall
Orthograptus? cf. *O. calcaratus* Lapworth
Dicranograptus nicholsoni Hopkinson
Crustacea:
Caryocaris sp.
Age: Zone 10 of Elles and Wood.

1–32–15 (USGS collection D695–CO), SW¼ sec. 29 (unsurveyed), T. 1 N., R. 37 E.
Dicranograptus cf. *D. ramosus* (Hall) (possibly variety *longicaulis* Elles and Wood)
Climacograptus sp.
Age: Probably zone 10 of Elles and Wood.

1–2–5 (USGS collection D688–CO), north-central part sec. 18, T. 1 N., R. 41 E.
Climacograptus sp.
Dicranograptus sp.
Age: The presence of *Dicranograptus* precludes a Silurian age. Probably Caradoc (Middle Ordovician).

2–10–15 (USGS collection D1103–CO), SE¼ sec. 7, T. 4 S., R. 38 E.
Orthograptus quadrimucronatus Hall
Glyptograptus? sp.
Diplograptus? sp.
Age: Zones 12–13 of Elles and Wood.

1–129–30 (USGS collection D694–CO), 1 mile west of sec. 31, T. 4 S., R. 41 E.
Collection includes *Climacograptus?* sp. No other forms identifiable.
Age: Uncertain. Middle Ordovician to Middle Silurian.

CAMBRIAN, ORDOVICIAN, AND MISSISSIPPIAN STRATA IN THE GRAPEVINE MOUNTAINS

Strata of Cambrian, Ordovician, and Mississippian Age crop out in the southernmost tip of Esmeralda County and consist of the Nopah Formation, the Pogonip Group, and unnamed shaly strata.

The strata of Cambrian and Ordovician Age in the Grapevine Mountains are of a different facies than in the rest of Esmeralda County. The Nopah Formation of Late Cambrian Age consists dominantly of massive dolomite, whereas the Emigrant Formation, which includes strata of the same age in the rest of the county, is composed dominantly of thinly interlayered limestone and chert. The Pogonip Group, locally of Early and Middle Ordovician Age, consists of limestone and shale, but the Palmetto Formation, which includes strata of the same age in the rest of the county, is composed of shale and siltstone and minor chert, limestone, and quartzite.

In north-central Nevada, Roberts and others (1958) have outlined three assemblages of lower Paleozoic strata, an eastern assemblage characteristic of the eastern part of Nevada and probably deposited in a myogeosynclinal environment, a western assemblage characteristic of the western part of Nevada and probably deposited in a eugeosynclinal environment, and a transitional assemblage occurring in intervening areas and representing an intermediate environment of deposition. The Nopah Formation and Pogonip Group clearly belong with the eastern assemblage of strata, whereas the Emigrant and Palmetto Formations are either of the transitional or of the western assemblage.

Nopah Formation

The Nopah Formation crops out in a few small areas along the southwest side of the county in the southernmost 4 miles. The formation is composed of banded light- to medium-gray dolomite and locally sandy dolomite. The prominent color banding in the formation is commonly referred to as "zebra stripes." Only the uppermost part of the formation is exposed in the county, although complete sections of the formation occur within a few thousand feet southwest of the county line. The thickness of the formation was not measured. The Nopah Formation is about 1,900 feet thick on Bare Mountain (Cornwall and Kleinhampl, 1961) 25 miles southeast of the southernmost tip of Esmeralda County and is probably of a comparable thickness in the complete exposures near the county line.

Pogonip Group

The Pogonip Group crops out in the same general areas as the Nopah Formation. It conformably overlies the Nopah Formation and consists of thin-bedded limestone, thinly interlayered limestone and shale, and shale containing limestone lenses a few inches long and a fraction of an inch thick. Locally some chert layers occur. A complete section does not occur in the county, but the formation is 1,375 feet thick on Bare Mountain (Cornwall and Kleinhampl, 1961) 25 miles southeast of the southern tip of the county, and 1,440 feet thick in the Quartz Spring area (McAllister, 1952, p. 11) about 30 miles to the southwest.

Two fossil collections were made in the Pogonip Group in Esmeralda County and another about 500 feet west of the Esmeralda County line in California. Based on the contained fossils, one collection is from strata probably correlative to the Ninemile Formation of the Pogonip Group, and the other two from strata correlative to the overlying Antelope Valley Limestone of the Pogonip Group (R. J. Ross, Jr., written communications, 1961 and 1962). The Ninemile Formation and Antelope Valley Limestone of the Pogonip Group were named and described by Nolan and others (1956, p. 27–29).

The fossil collections made by the writers are as follows: Identifications are by R. J. Ross, Jr.

676–14 (USGS collection D1019–CO), 2¾ miles northwest of southernmost tip of Esmeralda County, Nev., and ¼ mile east of Nevada-California State line.
Lachnostoma sp. (pygidium)
Ampyx? sp.
agnostid
Probably equivalent to the Ninemile Formation of central Nevada.

676–14a, same locality as 676–14 except 100 feet higher stratigraphically.
Orthidiella sp. (not enough specimens or well enough preserved to be sure of species)
Correlative with Ranger Mountains Member of Antelope Valley Limestone of Pogonip Group of Nevada Test Site and vicinity, Nevada (see Byers and others, 1961).

1253–8, ¼ mile northwest of southernmost tip of Esmeralda County, Nev., probably about 500 feet west of Nevada-California State line.
Orthidiella cf. *O. longwelli* Ulrich and Cooper
Same correlation as 676–14a above.

Shaly Strata of Mississippian Age

Shaly strata of Mississippian Age crop out in a small area along and near the southwestern border of the county 4 miles northwest of the southernmost tip of the county. These strata consist mostly of medium-dark-gray to dark-gray shale and siltstone that locally contain very thin beds of black limestone and 4- to 5-foot-thick layers of granule and pebble conglomerate containing fragments of limestone and chert. The shale commonly weathers grayish olive and locally contains pale-purple and light-greenish-gray parts. The conglomerate commonly contains poorly preserved pelmatozoan and brachiopod fragments.

The strata of Mississippian Age in the Grapevine Mountains are highly contorted and probably are separated from the topographically higher and probably overlying Nopah Formation and Pogonip Group by a low-angle or flat fault.

Two fossil collections were made in the Mississippian strata by the writers. Identifications are by Mackenzie Gordon, Jr. (written communication, 1962).

676–7J (USGS collection 20224–PC), 4½ miles northwest of southernmost tip of Esmeralda County, Nev., and about ⅜ mile east of Nevada-California State line.
Posidonia? sp.
Goniatites cf. *G. granosus* Portlock
The imprints in the altered shale very definitely tie it to the *Goniatites granosus* zone, which has been recognized in various parts of the Great Basin, as well as in much of the northern hemisphere. The nearest known occurrence of fossils of this zone to the present locality is in the Eleana Formation in the Nevada Test Site, where it occurs in unit H of Poole and others (1961). *G. granosus* also occurs in the lower part of the type Diamond Peak Formation in the section published by Brew (1961). This zone, in terms of the series of the American midcontinent, is known to occur in the lower part of the Chester Series.

676–8J (USGS collection 20223–PC), 4¼ miles northwest tip of Esmeralda County, Nev., and about ⅜ mile east of Nevada-California State line.
Dictoclostid indet. (small, fairly coarse ribbed productid)
Composita subquarata Hall?
Crinoid columnals
These fossils come from a somewhat limy pebbly conglomerate. They are associated with fragments of an organic detrital medium-grained limestone that contains small pelmatozoan and brachiopod fragments, as well as a single fragmentary shell that appears to be that of an *Aviculopecten*. The fossil remains are not complete enough to permit an age determination to be based on them.

PERMIAN STRATA

Diablo Formation

The Diablo Formation was named by Ferguson and others (1953) for Mount Diablo, a local name for a minor prominence a mile west of Candelaria. Candelaria is in the Candelaria Hills in Mineral County, Nev., 2 miles west of the Esmeralda County line. The Diablo Formation has not been studied by the writers, except for brief examinations, and the descriptions given here are largely from Ferguson and others (1953, 1954), Ferguson and Muller (1949, p. 45, 46, 49), and Page (1959, p. 18–21).

The Diablo Formation crops out along the south side of the Candelaria Hills north of Columbus, at several localities in the easternmost part of the Candelaria Hills, and at several localities in the southwestern part of the Monte Cristo Range. The formation unconformably overlies folded strata of the Ordovician Palmetto Formation and is overlain unconformably, but with no angular discordance, by the Candelaria Formation.

The Diablo Formation is quite variable in lithology and thickness. Near the county line it consists largely of sandstone and coarse grit. The grit is composed largely of quartz and gray, black, and red chert fragments derived from the underlying Ordovician rocks. This sandstone and grit are as much as 200 feet thick but are locally missing. Eastward in the Candelaria Hills dolomite is the dominant lithologic type, and north of Columbus the formation is 400 feet thick and consists entirely of dolomite. Farther east, in an isolated hill just east of U.S. Highway 95 and 9 miles north of Coaldale Junction, the formation again consists dominantly of conglomerate composed of Ordovician chert fragments. In the southwestern part of the Monte Cristo Range, the Diablo Formation is probably about 500 feet thick and consists of a basal conglomerate, overlain by interbedded dolomite, grit, and conglomerate.

The sandstone in the Diablo Formation contains *Punctospirifer pulcher* (Meek), *Neospirifer pseudocameratus* (Girty), and *Linoproductus eucharis* (Girty) (Ferguson and others, 1954), fauna characteristic of the Phosphoria Formation. The dolomite of the Diablo Formation contains corals including *Triplophyllum* and *Campophyllum*, and a brachiopod *Cleiothyridina* (Ferguson and others, 1953).

TRIASSIC AND TRIASSIC(?) ROCKS

Candelaria Formation

The Candelaria Formation was formally named by Muller and Ferguson (1936, p. 243) for the Candelaria mining camp in Mineral County, Nev., 2 miles west of the Esmeralda County line. The name, however, was first used informally in an unpublished report on the Candelaria mining district by J. A. Burgess in 1921. The formation has been only briefly examined by the writers and the description given below is taken mainly from Muller and Ferguson (1939, p. 1582–1583).

The Candelaria Formation has a limited distribution both in and outside of the county. It occurs in a discontinuous belt of outcrops on the north side of the Candelaria Hills from 16 miles west to 6 miles east of Candelaria. Only the easternmost part of this belt is in Esmeralda County.

The Candelaria Formation overlies the Diablo Formation. The contact is considered a marked erosional unconformity by Muller and Ferguson (1939), although Page (1959, p. 23) could find no conclusive evidence of such an unconformity in an area directly west of the Esmeralda-Mineral County line. In places, the Diablo Formation appears to have been entirely removed by pre-Candelaria erosion, and the Candelaria Formation rests with angular discordance on the Palmetto Formation of Ordovician Age.

At the type locality of the formation, 2 miles southeast of the Candelaria mining camp in Mineral County, Nev., the formation consists of greenish-brown, purple-gray, black, and olive-green shales and sandy shales, brown massive sandstone, and minor thin beds and lenses of limestone. Some of the sandstone beds probably contain tuffaceous material. Eastward from the type locality the shales grade laterally into sandstone and interbedded conglomerate. This sandstone also appears to be tuffaceous, and the conglomerate contains pebbles almost entirely of chert.

The Candelaria Formation is slightly over 3,200 feet thick at the type section, but the top of the formation is everywhere concealed by faulting, intrusive rocks, or Cenozoic rocks.

Fossils occur in bituminous shale and limestone from 150 to 270 feet above the base of the formation (Muller and Ferguson, 1939; Page, 1959). The fauna consists of ammonites and pelecypods dated as Early Triassic.

Excelsior Formation

The Excelsior Formation was named by Muller and Ferguson (1936, p. 244) for outcrops in the Excelsior Mountains in Mineral County, Nev., about 14 miles northwest of Esmeralda County. The formation crops out (1) in the easternmost part of the Candelaria Hills, (2) in the southwestern and northeasternmost parts of the Monte Cristo Range, (3) in the southern part of the Cedar Mountains, and (4) in several outcrops in the Royston Hills. The Excelsior Formation has been only briefly examined by the writers and the description given here is mainly from Ferguson and Muller (1949, p. 38, 46, and 49) and Ferguson and others (1953).

In the eastern part of the Candelaria Hills, the Excelsior Formation rests on the Palmetto Formation of Ordovician Age with a marked unconformity. This is the only area in the county where the base is exposed. The formation is overlain unconformably in the county by the Dunlap Formation; this contact is exposed in the county only in the southern part of the Cedar Mountains.

The Excelsior Formation is nowhere found in sedimentary contact with the Candelaria Formation, and it is presumed that the two are present in different plates of a major thrust. This relationship is suggested by mapping (Ferguson and Muller, 1949, figs. 8 and 10) in the Candelaria Hills and Monte Cristo Range where the Ordovician strata are overlain in some places by the Permian Diablo Formation which in turn is succeeded by the Candelaria Formation, whereas in other places the Ordovician strata are overlain by the Excelsior Formation. A low-angle or "thrust" fault, the Monte Cristo thrust, is mapped between the different stratigraphic successions. The upper plate contains the Palmetto, Diablo, and Candelaria Formations, whereas the lower plate contains the Palmetto and Excelsior Formations.

In the Candelaria Hills, the Excelsior Formation consists of greenstone breccia with rare thin flows and dikes of similar lithologic character. A few thin beds of tuffaceous sandstone are the only sedimentary rocks. In the southwestern part of the Monte Cristo Range, the Excelsior Formation consists of greenstone breccia and greenstone similar to that in the Candelaria Hills. In the extreme northwest of the Monte Cristo Range and on Cedar Mountain, the Excelsior consists of argillite and greenstone with some chert and tuff. As has been pointed out by Ross (1961, p. 19), however, thin sections of rocks resembling chert in Mineral County exhibit a clastic texture with angular silt- to fine-sand-sized quartz fragments scattered in a finer grained mosaic of quartz, feldspar, and mica. The chert may be, therefore, silicified siltstone. Ross (1961, p. 17–19) indicates that in Mineral County the Excelsior Formation contains a variety of rock types including (1) rhyolitic rocks such as soda rhyolite and quartz latite, (2) intermediate rocks of the rhyodacite and dacite groups, (3) andesitic rocks, and (4) fine-grained tuffaceous clastic rocks. The Excelsior Formation in Esmeralda County also may include this same variety of rocks.

The thickness of the Excelsior Formation is not known in Esmeralda County, but the thickness in Mineral County is estimated to be about 12,000 feet.

The age of the Excelsior Formation is based on a single fossil locality in the Gillis Range in Mineral County, about 50 miles northwest of the Esmeralda County line. The fossils occur in lenticular limestones and shales interbedded with lavas and volcanic breccia. Muller and Ferguson (1939, p. 1589) indicate an early Middle Triassic Age for these fossils. N. J. Silberling (*in* Ross, 1961, p. 19) indicates that although this precise age assignment might be questioned, the fauna is probably at least indicative of the Middle or lower Upper Triassic.

Considerable uncertainty exists, however, about the age of the Excelsior Formation and similar volcanic assemblages in Esmeralda County and adjacent regions. Muller and Ferguson (1936, p. 245) originally assigned the Excelsior Formation to the Middle Triassic on the basis of the single fossil locality in the Gillis Range, but similar rocks in western Nye County to the east of Esmeralda and Mineral Counties were assigned to the Pablo Formation of probable Permian Age. As has been discussed by Ross (1961, p. 20), much of the strata assigned to the Excelsior Formation in Mineral County could possibly be assigned to the Pablo Formation of Permian Age. Some or all of the Excelsior Formation in Esmeralda County could also be Permian in age.

JURASSIC STRATA

Dunlap Formation

The Dunlap Formation was named by Muller and Ferguson (1936, p. 250) for strata west of Dunlap Canyon in the Pilot Mountains in Mineral County, 12 miles northwest of the Esmeralda County line. The formation has not been examined by the writer and the description given here is from Muller and Ferguson (1939, p. 1616–1622), Ferguson and Muller (1949, p. 38), and Ferguson and others (1953).

The Dunlap Formation crops out in the county only in a few small areas in the southern part of Cedar Mountain. Here it is composed of conglomerate, sandstone, shale, and a little marine limestone. Red sandstone is predominant, and the conglomerates are composed predominantly of chert pebbles.

In the southern part of Cedar Mountain the Dunlap Formation rests unconformably on the Excelsior Formation. To the north and northwest in Mineral County, however, several formations of Triassic and Jurassic Age intervene between the Excelsior and Dunlap Formations. The Dunlap Formation is the youngest Mesozoic sedimentary unit in Esmeralda County and adjacent regions.

The Dunlap Formation varies greatly in lithologic character regionally. The amount of conglomerate and limestone is particularly variable. As has been outlined by Muller and Ferguson (1939, p. 1616–1617) and by Ferguson and others (1953), the Dunlap Formation was deposited for the most part after the emergence and the beginning of folding of older Mesozoic formations. The formation lies locally in troughs produced by this folding and the conglomerates were shedding off nearby orogenic highs.

Ammonites and pelecypods occur in the Dunlap Formation in the Excelsior Mountains and Garfield Hills in southeastern Mineral County, Nev. These fossils indicate an Early and Middle Jurassic Age for the formation.

MESOZOIC AND TERTIARY PLUTONIC ROCKS

Coarse-grained plutonic rock, most of which has the composition of quartz monzonite, crops out in some 30 separate bodies ranging in size from a few acres to about 400 square miles. The largest masses are the Sylvania pluton having a total outcrop area of about 225 square miles, and the Inyo batholith having a total outcrop area of about 400 square miles (fig. 7). Most of the Sylvania pluton lies within the boundaries of Esmeralda County, but only a small part of the Inyo batholith is within the county. Plutonic masses that lie entirely within the county and which are given names for descriptive purposes include Lone Mountain pluton (28 sq mi), Weepah pluton (10 sq mi), Mineral Ridge pluton (3 sq mi), Palmetto pluton (32 sq mi), Palmetto Wash pluton (35 sq mi), and Dyer pluton (2 sq mi).

The plutonic rocks typically have a medium- to coarse-grained (2 to 5 mm) equigranular texture and are light to medium gray. Most are nonporphyritic although porphyritic phases with phenocrysts of K-feldspar an inch or so across occur locally.

A total of 50 hand specimens, collected from the various plutonic bodies, were sawed and stained with potassium cobaltinitrite. The distribution of these specimens is shown on figure 7. Modal analyses were made of the sawed specimens, using the methods of Jackson and Ross (1956), and thin sections of about 35 specimens were examined. The results of the modal analyses are shown in figure 8. Using the classification of Johannsen (1939, p. 144), shown in this figure, it is seen that the bulk of the plutonic rocks of Esmeralda County are in the quartz monzonite field while half a dozen are in the granodiorite field, and a few varieties low in quartz fall in the range of diorite, monzonite, and syenite.

Textures are either xenomorphic or hypidiomorphic granular in all specimens examined. Plagioclase, K-feldspar, and quartz are the essential minerals; biotite, hornblende, and locally muscovite, are varietal minerals; and sphene, apatite, and black opaques are common accessories. Biotite is much more abundant than hornblende and commonly makes up 5 to 15 percent of a specimen. The plagioclase in nearly all specimens is oligoclase or sodic andesine as determined from extinction angles and indices of refraction. Perthitic K-feldspar is present in some specimens, but on the whole it is not prominent. Myrmekitic intergrowths of quartz in K-feldspar are fairly common in some bodies of quartz monzonite. These intergrowths encroach on plagioclase and other minerals and seem clearly to have been the last material to crystallize.

The various plutonic bodies penetrate to different stratigraphic levels ranging from the lowest Precambrian unit, the Wyman Formation, in the southern and central part of the county to Jurassic rocks in the northern part. Most plutons have sharp contacts with enclosing rocks, and in detail most contacts are highly discordant. However, some of the larger plutons are grossly concordant with, and occupy the cores of, gently plunging anticlines of approximately parallel northwest trend. The Lone Mountain pluton, Weepah pluton, Mineral Ridge pluton, the Sylvania pluton in part, and an unnamed pluton north of Clayton Valley are in this category (pl. 1).

The contacts of the Mineral Ridge pluton, a pluton with unique characteristics, are highly irregular in detail, reflecting in part the contorted condition of the Wyman Formation which it intrudes. An abundance of coarse pegmatitic material and quartz is commonly present in the Wyman at the contact with the quartz monzonite and for several

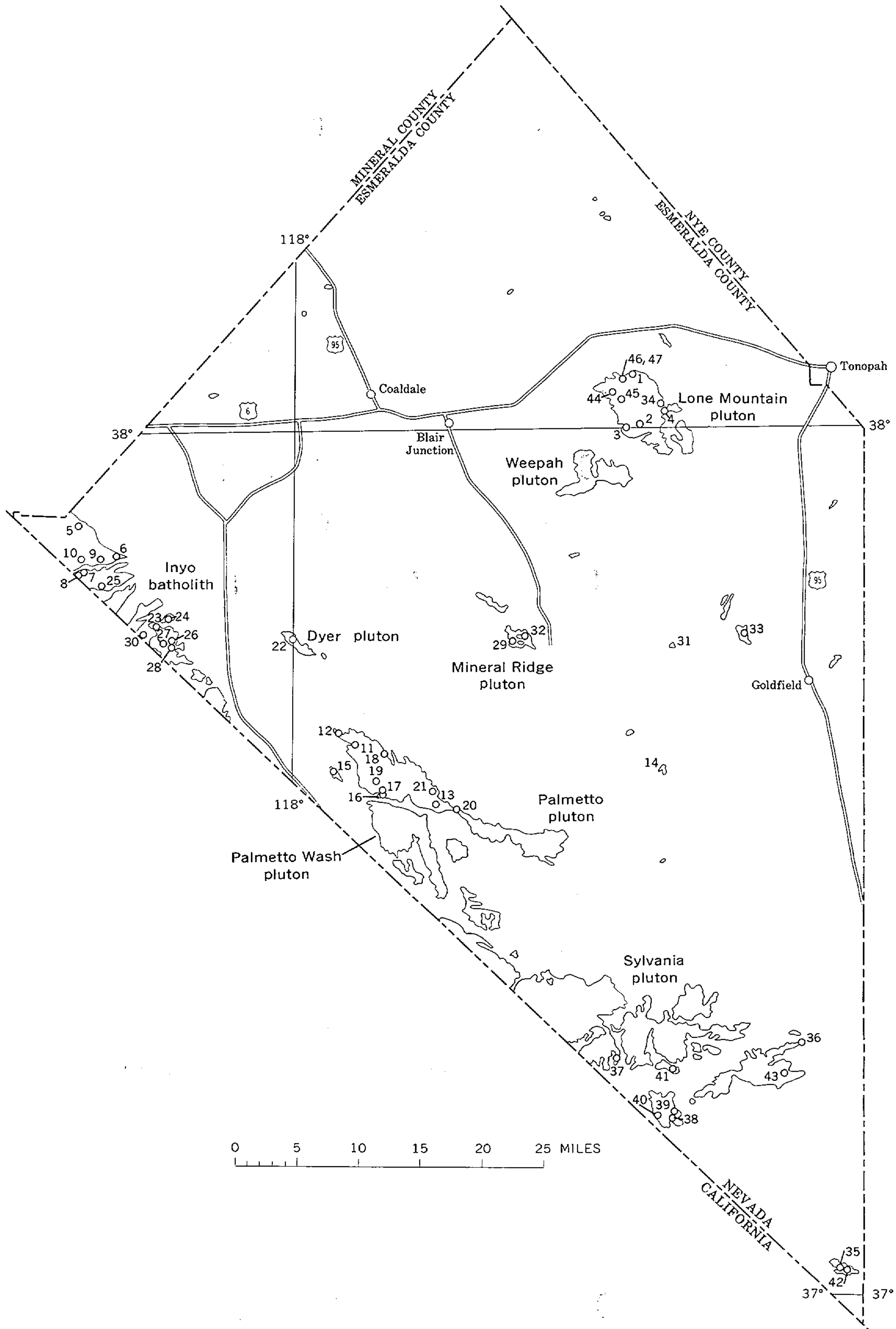

Figure 7. Distribution of plutons and samples of plutonic rocks.

8 0 0 2 2 2 0 9 9

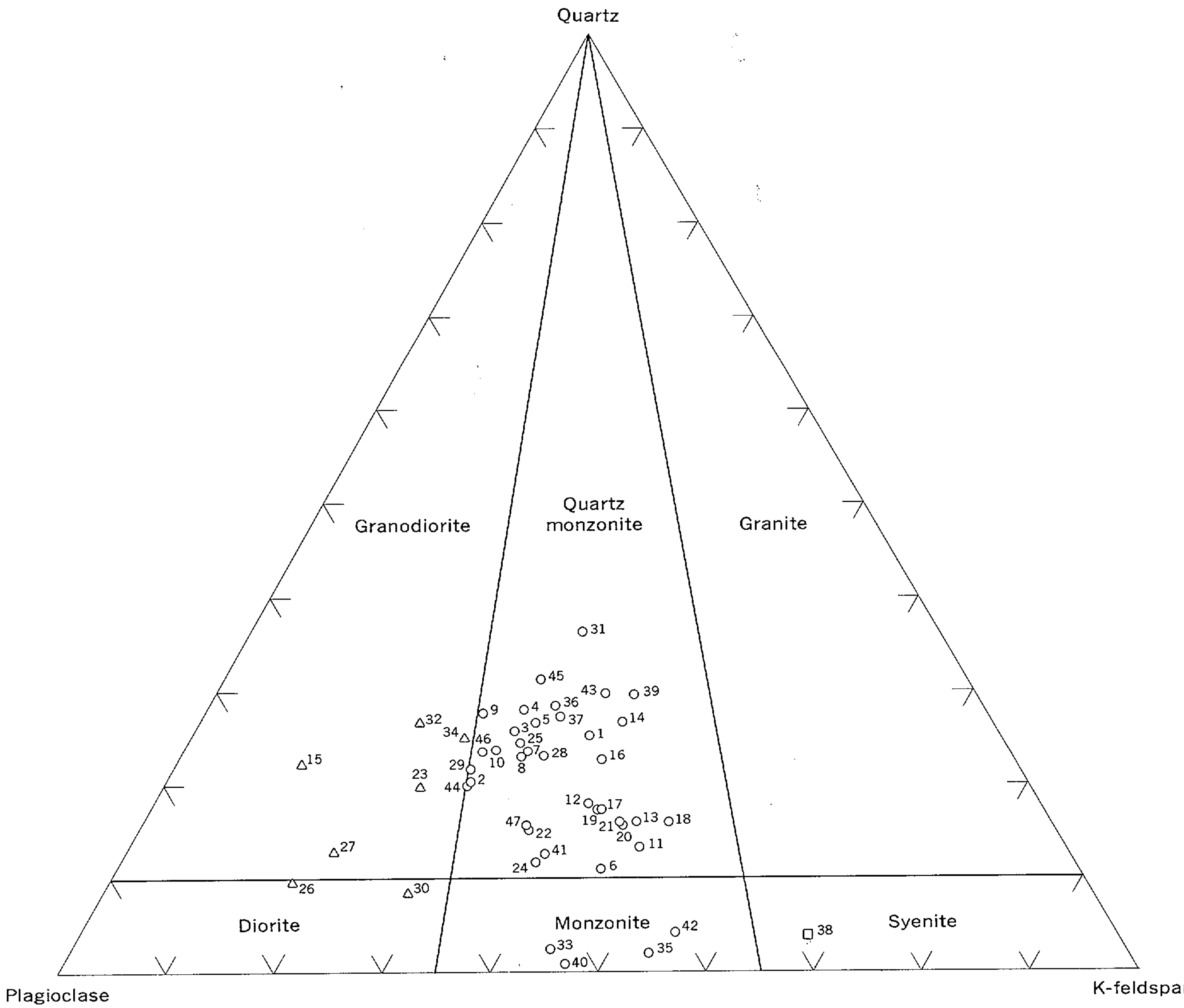

Figure 8. Diagram showing modal analyses of 49 specimens of plutonic rocks.

tens to several hundreds of feet above it. The pegmatite is in layers approximately parallel to bedding and in places seems to replace the cores of small folds. Quartz occurs similarly and also in veins along high-angle faults. In many places the Wyman is highly silicified for tens of feet above the contact. The quartz monzonite, which contains biotite as the principal mafic mineral, commonly shows planar structure that, in gross aspect at least, is concordant with the Wyman contact. In places the quartz monzonite is cut by irregular pegmatite bodies near the contact.

An aureole of strongly metamorphosed rock ranging up to about 2 miles in outcrop width surrounds each of the exposed plutonic bodies. Argillaceous rocks are commonly metamorphosed to hornfels or to knotty slate, phyllite, or, rarely, schist. Argillite of the Excelsior Formation in the northern part of the county is highly silicified to a cherty hornfels over extensive areas adjoining small intrusive bodies. Calcareous rocks within the aureoles are commonly altered to marble and to calcsilicate hornfels consisting largely of garnet and epidote.

The more strongly metamorphosed rocks near the plutons pass outward into rocks that appear but little altered to the naked eye. However, thin section study shows that pre-Tertiary pelitic rocks throughout the county have apparently undergone a pervasive low-grade metamorphism, shown by their abnormally high percentage of secondary quartz, chlorite and white mica, and by their crystalloblastic texture.

The proximity and lithologic similarity of the Lone Mountain and Weepah plutons strongly suggest that the two are connected at fairly shallow depth with only a narrow septum of older rocks intervening near the surface (pl. 1). Likewise, the Palmetto, Palmetto Wash, and Sylvania plutons are separated by only narrow septa of invaded rock and are almost certainly connected at depth. The narrow range in composition shown by the plutonic rocks throughout the county (mainly biotite quartz monzonite), the wide distribution of plutons, and the ubiquitous though low-grade thermal metamorphism shown by preplutonic rocks strongly suggest that a continuous, fairly shallow, subjacent mass of granitic rock extends beneath most of the county. It is worthwhile to note in this connection that Ross (1961, p. 32) found quartz monzonite to be the dominant rock forming the plutons throughout Mineral County, which lies adjacent to Esmeralda County on the northwest. He also pointed out that the Mineral County plutonic rocks show affinities with the intrusive rocks of the Sierra Nevada, an observation that applies equally well to the rocks of Esmeralda County. Moreover, in view of the close lithologic similarity and spatial relation of the plutonic rocks of Esmeralda and Mineral Counties and those of the Sierra Nevada batholith, and in view of the relatively greater abundance of these rocks in the western parts of both counties, the writers are inclined to agree with Ross' suggestion (1961, p. 30) that the batholith is continuous eastward beneath Mineral County, and would add that it probably extends beneath Esmeralda County as well. If this inference is correct, the eastern limit of the Sierra Nevada batholith at the latitude of Esmeralda County is actually about 75 miles east of what has traditionally been considered its eastern front.

The plutonic rocks in Esmeralda County may have been emplaced at several different times, although presently available radiometric ages of these rocks do give a clear picture. The Sylvania pluton seems to be of Middle Jurassic Age on the basis of three K-Ar ages (table 2), and this age is similar to that of most of the granitic rocks in the White-Inyo Mountains a short distance to the west in California (McKee and Nash, 1967). Two dates have been determined on rocks of the Palmetto pluton; one indicates a Jurassic age and the other a Cretaceous age. One of these two dates could be in error, or, alternately, the pluton could be composite and contain rocks of more than one age. Three ages have been determined on the Lone Mountain pluton (367 million years on hornblende from one of a series of hornblende dikes that cut the pluton, and 67 and 19 million years on biotite from granitic rocks of the pluton itself). More radiometric work on rocks of the Lone Mountain pluton will be necessary before the discrepancies between these ages can be resolved. The Mineral Ridge pluton appears to be of early Tertiary Age on the basis of two K-Ar ages (one from muscovite and one from biotite). Bailly and Compton (1955), however, have measured an age of 700 million years by Ahrens' Rb-Sr method from lepidolite in granite pegmatite from Mineral Ridge.

TABLE 2. Potassium-argon age determinations of some Esmeralda County plutons.

[Sample analysis: SP−1 − SP−3, 1014−1018, U.S. Geol. Survey; KA840, Univ. of California, Berkeley; B−0321, Geochron. Labs., Inc. (Schilling, 1965)]

Sample no.	Pluton	Mineral	K_2O (percent)	$Ar^{*40}/K^{40} \times 10^{-3}$	Radiogenic argon (percent)	Age (m.y.)	Geochronologists
SP−1	Mineral Ridge	Muscovite	9.87	2.99	73.0	51±2	R. W. Kistler
SP−2	Mineral Ridge	Biotite	4.67	2.49	27.0	42±2	R. W. Kistler
1014	Palmetto	Hornblende(?)	0.625	7.80	75.6	129±6	J. D. Obradovich
1015	*Palmetto*	*Biotite*	7.89	11.55	89.3	188±7	J. D. Obradovich
1016	Lone Mountain[1]	Hornblende	0.862	23.65	94.6	367±18	J. D. Obradovich
1017	Lone Mountain	Biotite	7.39	4.00	83.4	67.2±3	J. D. Obradovich
SP−3	Lone Mountain	Biotite	7.69	1.145	35.0	19.5±1	R. W. Kistler
1018	Sylvania	Biotite	8.62	9.03	96.1	149±6	J. D. Obradovich
KA 840	Sylvania	Biotite	8.43	9.45	75.5	155±6	J. D. Obradovich
B−0321	Sylvania	Biotite	7.91	8.93	90.0	153±5	Geochron. Lab.

[1]Hornblende is from one of a series of hornblende diorite dikes that cut the Lone Mountain pluton.

TERTIARY ROCKS

It may reasonably be inferred from the absence of Upper Jurassic and Cretaceous sedimentary rocks in Esmeralda County, as well as in an adjoining large area in western Nevada and eastern California, that the region stood above sea level, was not subjected to volcanic activity, but was probably undergoing deformation, and being intruded by plutonic rocks and intensely eroded during that interval of time. This environment almost certainly prevailed well into the Tertiary as the oldest Tertiary rocks within the county are volcanic rocks of Oligocene Age exposed in a relatively small area east of Goldfield. Sedimentary rocks, also of Oligocene Age, crop out just beyond the southern tip of the county in the Titus Canyon area (Stock and Bode, 1935).

On the basis of presently available fossil and radiometric age data (table 3), it appears that neither volcanism nor sedimentation, having once started, was continuous through the latter part of the Tertiary. An early episode of volcanic activity probably took place in the vicinity of Goldfield about 25 to 26 million years ago, and a general period of volcanism that affected all but the southern part of the county took place about 21 to 22 million years ago. The oldest sedimentary deposits are probably about 17 million years old, and the bulk of sedimentary deposits probably formed 10 to 13 million years ago. The interval between 16 and 13 million years seems to have been one during which neither volcanism nor sedimentation was taking place anywhere in the county although an anomalous age of 15.1 m.y. has been obtained for the Gilbert Andesite which *overlies* the 10 to 13 m.y. old sedimentary sequence. An interval of nondeposition seems to have prevailed also in the late Pliocene, from approximately 5 to 2 million years ago.

Tertiary rocks in the county include welded and nonwelded ash flows, lava flows, volcanic breccia, and fresh-water sedimentary rocks. The volcanic rocks range in composition from rhyolitic to basaltic; those having the composition of quartz latite are most common. The thickness of the Tertiary section as well as its lithologic character differs greatly from one range to another within the county. The maximum thickness is in the Silver Peak Mountains where a pile of sedimentary and volcanic rocks several thousand feet thick is exposed. Because the lithologic composition of the Tertiary differs from area to area, the county has been divided into seven different areas to facilitiate treatment of the Tertiary rocks on the geologic explanation (pl. 1).

Tertiary rocks, both sedimentary and volcanic, are very important from an economic standpoint in that they are hosts for the most important deposits of minerals produced in the county. Diatomite, a siliceous sedimentary rock, is being mined by the Great Lakes Carbon Corp. and has for a number of years been the county's most important mineral product. Currently, the Foote Mineral Co. is producing lithium from saline brines contained in the sedimentary deposits of Clayton Valley. Some of these deposits may be of late Tertiary Age. In earlier years, boron was produced from Tertiary sedimentary rocks in the Fish Lake Valley and Columbus Salt Marsh.

Tertiary volcanic rocks are the hosts for deposits of precious metals and quicksilver. The rich gold ores taken from the Goldfield district were mainly in dacite and andesite; the silver deposits of the Divide district were in a rhyolitic welded ash flow; the silver deposits of the Red Mountain district in the Silver Peak Mountains (Mohawk and Sixteen-to-One mines) are in silicic flows; and most quicksilver deposits at the north end of the White Mountains are in opalized tuffaceous rocks.

Character and Nomenclature of the Esmeralda Formation and Siebert Tuff

Many of the Tertiary sedimentary rocks north of the Palmetto Mountains have in the past been referred to as the Esmeralda Formation (Turner, 1900, p. 198). Turner's type locality is in the central part of Esmeralda County, and his original definition states:

> "The fresh-water deposits treated of in this paper may be designated the Esmeralda formation, the name being taken from the county in which they occur. The beds are composed of sandstones, shales, and lacustral marls, with local development of breccia and conglomerate on a large scale."

While recognizing that volcanic rocks are interlayered with the sedimentary beds, Turner (1900, p. 205) nevertheless clearly seems to have excluded volcanic rocks except for a few thin layers of tuffaceous material in his definition of the formation.

Turner (1900, p. 198) conceived that a large lake, "Lake Esmeralda," bounded on the east by the Montezuma Range (pl. 1), on the west by the Inyo Range, and extending northward an unknown distance from the Palmetto Mountains came into being in Miocene time and probably existed well into the Pliocene. This became the site of deposition of fresh-water sedimentary rocks having a maximum thickness of 14,800 feet (Turner, 1900, p. 202).

Whereas Turner (1900) clearly excluded all volcanic rocks except a few thin tuffaceous layers from the Esmeralda Formation, Ferguson (1924, p. 43), included several thick volcanic members in his description of the Esmeralda in the Manhattan district northeast of Esmeralda County, and Ferguson and others (1953) included a lower breccia and tuff member and an upper sedimentary member in the Esmeralda of the Coaldale quadrangle in the northern part of the county.

Recent mapping in the Silver Peak Mountains has shown the presence of at least three discrete units of sedimentary rocks separated stratigraphically by thick sections of volcanic rock. The distribution of these sedimentary units is approximately the same as the distribution of the Esmeralda Formation shown on Turner's map (1900, pl. XXIV). It is therefore apparent that Turner's Esmeralda in the Silver Peak Mountains is not a continuous section of sedimentary rocks but is interrupted by great thicknesses of volcanic rocks interlayered with diverse sedimentary facies.

If, in the Silver Peak Mountains, the definition of the name Esmeralda were now to be broadened to include interlayered volcanic units as Ferguson (1924) and Ferguson and others (1953) had done elsewhere, then most of the highly variable lithologic types of Tertiary rocks in the area

TABLE 3. Potassium-argon age determinations of volcanic and tuffaceous sedimentary rocks in Esmeralda County and adjacent areas.

Source of data	Rock unit and locality	Mineral	K_2O percent	Ar^{40} rad mole/gm	Ar^{40} rad / Ar^{40} total	Apparent age (million years)
*	Air-fall tuff in Tertiary seds. Sec. 3, R. 38 E., T. 7 S., lat 37°22′N., long 117°47′W. (Inyo County, Calif.)	Biotite	7.30(2)	4.62×10^{-11}	0.28	4.3±0.4
	Rhyolite tuff breccia (Taf); sec. 16, R. 39 E., T. 6 S., lat 37°25′N., long 117°40′W. Dated by J. D. Obradovich, Univ. of California, Berkeley, 1961, U.C. KA 839; E. H. McKee, Ph.D. thesis, Univ. of California, Berkeley, 1962.	Biotite	5.79	3.81×10^{-11}	0.42	4.5±0.2
* R_3	Basalt flow (Qtb); sec. 36, T. 2 S., R. 35 E., lat 37°44′N., long 118°2′W.	Whole rock	2.55(2)	1.82×10^{-11}	0.08	4.8±0.2
† R_3	Latite flow (Tpl); sec. 2, T. 3 S., R. 38 E., lat 37°42′11″, long 117°44′W.	Biotite	8.29(2)	7.28×10^{-11}	0.50	5.9±0.2
* R_3	Rhyolite ash-flow tuff (Tafu), lat 37°47′N., long 117°51′W.	Biotite	8.48(2)	7.58×10^{-11}	0.28	6.0±0.5
* R_3	Quartz-latite welded tuff (Tawu), lat 37°42′N., long 117°51′W.	Biotite	8.60(2)	7.78×10^{-11}	0.41	6.1±0.3
R_3	Air-fall tuff, sec. 15, R. 39 E., T. 1 S., Robinson and others, 1968, table 1, no. 13.	Biotite	(not available)	(not available)	(not available)	6.9
R_1	Air-fall tuff (Tsl), lat 37°56′N., long 118°6′W., Evernden and others, 1964, p. 177.	Biotite	5.59	do.	0.64	11.1
R_1	Air-fall tuff, lat 37°56′N., long 118°6′W., Evernden and others, 1964, p. 177.	Biotite	7.37	do.	0.69	11.4
R_2	Air-fall tuff(?) (Ts_2); sec. 33, R. 37 E., T. 2 N., lat 37°59′N., long 117°51′W., Evernden and James, 1964, p. 970.	Biotite	8.25	do.	0.69	12.7
* R_3	Air-fall tuff in Tertiary seds. Sec. 3, R. 38 E., T. 7 S., lat 37°22′N., long 117°47′W. (Inyo County, Calif.)	Biotite	5.68(2)	10.98×10^{-11}	0.177	13.1±1.0
*	Gilbert Andesite (Tg). Near road to South Gilbert about 3 miles ± north of U.S. 95.	Biotite	8.12(2)	18.16×10^{-11}	0.66	15.1±0.6
†	Brougher Dacite (Tl); sec. 10, T. 1 N., R. 42 E., lat 37°57′N., long 117°15′W.	Sanidine	10.90(2)	26.17×10^{-11}	0.94	16.2±0.4
†	Brougher Dacite (Tl) (same as above)	Biotite	7.77(2)	18.72×10^{-11}	0.62	16.2±0.4
†	Dacite flow (Td); sec. 33, T. 1 N., R. 43 E., lat 37°43′N., long 117°15′W.	Hornblende	0.96(2)	2.97×10^{-11}	0.54	20.8±0.7
	Dacite vitrophyre (Taw), lat 37°42′N., long 117°15′N. Dated by R. W. Kistler, U.S. Geological Survey.	Biotite	7.21	(not available)	0.70	21.1
R_3	Rhyolite welded tuff (Taw); sec. 31, R. 37 E., T. 2 N., lat 37°59′N., long 117°54′W., Robinson and others, 1968, table 1, no. 12.	Biotite	do.	do.	do.	21.5
†	Milltown Andesite (Tml); sec. 30, T. 2 S., R. 42 E., lat 37°44′N., long 117°12′W.	Hornblende	0.85(2)	2.72×10^{-11}	0.58	21.5±0.5
†	Dacite flow (Td); sec. 33, T. 1 N., R. 43 E., lat 37°43′N., long 117°15′W.	Biotite	5.65(2)	18.13×10^{-11}	0.75	21.6±0.5
*	Rhyolite welded tuff (Taw), lat 38°1′N., long 118°7′W.	Biotite	7.88(2)	26.65×10^{-11}	0.63	22.8±1.0

$\lambda_\epsilon = 0.585 \times 10^{-10}$ year^{-1}
$\lambda_\beta = 4.72 \times 10^{-10}$ year^{-1}
K-40/K = 1.19×10^{-4} atom percent

*Age determination by E. H. McKee, U.S. Geological Survey Isotope Laboratory, Menlo Park, Calif.
†Age determination by M. A. Lanphere and J. C. Engels, U.S. Geological Survey Isotope Laboratory, Menlo Park, Calif.
R_1 Evernden and others (1964).
R_2 Evernden and James (1964).
R_3 Robinson and others (1968).

K-Ar ages were obtained from biotite, hornblende, sanidine, and whole rock. In one case the mineral pair of biotite and sanidine from the same specimen of dacite (Brougher) was dated. The argon analyses were made by standard isotope-dilution techniques using a Nier-type, 6-inch-60°-sector mass spectrometer. Potassium was analyzed by flame photometry, using a lithium internal standard.

Owing to uncertainties in the argon and potassium analyses, the analytical precision at the 68 percent confidence level of the calculated ages in the isotopic composition and concentration of the Ar^{38} tracer, and in the concentration of the flame photometer standards, is from 2 to 8 percent. All samples but one, however, have an error of no more than 4 percent.

would have to be included and the name would become so generalized a term as to be virtually meaningless. In view of these conditions the name Esmeralda Formation should be either abandoned or used in a restricted local sense in reference to a single sedimentary lithologic unit. The latter alternative is followed here.

Robinson and others (1968) have recently described the Cenozoic rocks of central Esmeralda County and designated the type section of the Esmeralda Formation to be the sedimentary rocks in the Alum area, southwestern part of Weepah Hills (pl. 1). They state that this sequence of rocks measures more than 9,000 feet thick and crops out over an area of about 40 square miles in the southern part of Big Smoky Valley.

In this report we use the name Esmeralda Formation in the very restricted sense to apply only to the exposures of sedimentary rocks in the Weepah Hills, which includes the type section of Robinson and others (1968). The sequences in the Silver Peak Range, Fish Lake Valley, and other areas included in Turner's original Esmeralda Formation are similar in general aspect to the type section but differ greatly in detail and were deposited in discrete local basins separate from that of the type section. They are designated merely as sedimentary rocks for purposes of this report.

The name Siebert Tuff is retained but used in the restricted sense of Spurr (1905, p. 54) and Ransome (1909a, p. 66) rather than in the broad sense of Knopf (1921, p. 150–153) in that it refers principally to the sedimentary unit that crops out on the east slope of Siebert Mountain — the type locality — in the Tonopah district. The name is also used for lithologically similar rocks presumably of the same age in the Goldfield area. The Siebert Tuff has in the past (Ferguson, 1924, p. 42) been correlated with Turner's (1909) Esmeralda Formation, but potassium-argon radiometric dates recently obtained on the Brougher Dacite, which intrudes the Siebert, indicate that the Siebert is probably 4 to 5 million years older than the oldest beds of the Esmeralda. Therefore, the Siebert, which is now considered to be Miocene, was probably formed earlier than the Esmeralda and in a separate basin.

DETAILED DESCRIPTION OF TERTIARY ROCKS

Tentative correlations of Tertiary rocks are given on the explanation of plate 1 and are based in part on about a dozen scattered radiometric age determinations and in part on the correlation of lithologically similar rock units and sequences of units. A description of the Tertiary rocks in the seven areas shown on the explanation follows.

Goldfield Hills, Montezuma Range, Clayton Ridge, and Mount Jackson Ridge

About fifteen Tertiary rock units are recognized in the east-central part of Esmeralda County. Twelve of these units, including some that probably are the oldest Tertiary rocks in the county, crop out in the Goldfield mining district. Ransome (1909a) mapped nineteen Tertiary formations in the district, but we believe some of his units are correlative (the Morena Rhyolite with his Sandstorm Rhyolite and the Kendall Tuff with the latite). Other units of Ransome, including the Rabbit Spring Formation, andesite dikes, andesite breccia, and Espina Breccia, either are not exposed in Esmeralda County or are too small to be shown on the scale of the county map.

The oldest Tertiary unit in the Goldfield district, and apparently the oldest in the county, is the Vindicator Rhyolite, an argillized and silicified welded ash flow of rhyolitic composition which crops out in two localities. The Vindicator shows definite eutaxitic structure in most though not all places and contains moderately abundant quartz phenocrysts. E. B. Ekren, R. E. Anderson, and R. P. Ashley of the U.S. Geological Survey have indicated (oral communication, 1965 and 1969) that the Vindicator Rhyolite is petrographically similar to a welded ash flow mapped in the Cactus Range in Nye County about 20 miles east of Esmeralda County. This ash-flow tuff in the Cactus Range has a K-Ar date of 25.6 million years. If this correlation is correct the volcanic activity in the Goldfield area began as far back as late Oligocene or early Miocene time.

Next above the Vindicator Rhyolite in the Tertiary section at Goldfield is Ransome's latite (1909a, p. 38) and Kendall Tuff (Ransome, 1909a, p. 41). Ransome placed the Kendall above the latite in his column, but recent remapping, by J. P. Albers, of the Goldfield district has shown that these two units are lithologically similar and apparently lie at the same stratigraphic position. The Kendall Tuff contains discrete flattened dark fragments that are interpreted to be collapsed pumice fragments, which suggests that the Kendall is an altered welded ash flow. The latite of Ransome also contains tuffaceous lenses or layers with similar-appearing dark flattened fragments, although the main bulk of the latite consists of lava flows that show good flowage banding which locally dips steeply and is highly contorted. The petrography and composition of the latite and Kendall Tuff appear closely similar, although the Kendall is so weathered and altered that its original mineral components are no longer determinate. Thin sections show the latite to be composed of sparse to moderately abundant plagioclase phenocrysts up to 3-mm grain size and as calcic as An_{55} but mostly much more sodic. Phenocrysts of ferromagnesian minerals are altered to iron oxide leucoxene and abundant magnetite. The groundmass is commonly altered and consists of fine white mica, calcite, chlorite, black opaques, and clay minerals. The mineralogy of the tuffaceous beds in the latite is similar to that of the lava except that there is a distinct alinement of mineral components in most specimens. The dark elongate lithoidal fragments in the tuff consist of fine-grained clay minerals, quartz, and tiny specks of black opaques.

Because Ransome's (1909a) Kendall Tuff and latite are similar in composition and general stratigraphic position, it is inferred that they had a common origin. Consequently the two units are combined as one map unit on the county map.

The latite and Kendall Tuff are overlain by the Sandstorm Rhyolite (Ransome, 1909a, p. 43). This unit includes rhyolite flows, small rhyolite plugs, welded rhyolitic ash flows, volcanic breccia, air-fall tuff, and lenticular beds of tuffaceous shale and shale. Because of this heterogeneous lithology the name Sandstorm Rhyolite is here renamed Sandstorm Formation.

The welded ash flows of the Sandstorm have distinct collapsed pumice fragments and occur within a sequence of rhyolite flows and breccia. The ash flows contain abundant phenocrysts and clasts of quartz and sanidine and little or no plagioclase. Original ferromagnesian minerals are completely altered to clay minerals and iron oxide. Ransome's Morena Rhyolite, according to R. P. Ashley (oral communication, 1969), is a welded ash flow identical to ash flows associated with the Sandstorm Formation. In this report, it is considered as part of the Sandstorm Formation and the name Morena Rhyolite is abandoned.

The fluidal rhyolites of the Sandstorm show a variety of structures and textures. Some facies exhibit well-defined locally contorted flowage banding; others have strongly developed platy structure, and some are massive. Quartz phenocrysts range from abundant to very sparse. Most of the rhyolite is probably extrusive but some is intrusive into the Kendall Tuff and the Palmetto Formation. The volcanic breccia is rhyolitic and locally contains layers of bedded tuff. Shale and tuffaceous shale in the Sandstorm occur as lenses and are gray to black, generally platy, and have yielded no fossils.

The Milltown Andesite overlies the Sandstorm Formation unconformably and is the most extensively exposed unit in the Goldfield area. It commonly contains fairly abundant plagioclase (An_{50}) phenocrysts that average 0.5 to 1.0 mm across. The abundance and size of these phenocrysts, along with absence of quartz, distinguish the Milltown Andesite from the dacite which lies next above the andesite in the section. Other primary mineral components of the andesite include augite, hornblende, and pigeonite. Alteration of the andesite ranges from slight to extreme. In slightly altered facies the alteration minerals include magnetite, chlorite, fine white mica, and calcite; in the large extremely altered masses the mineral components are chiefly kaolinite, quartz, alunite, fine white mica, and montmorillonite. It is noteworthy that even in the highly altered facies pseudomorphs of the small plagioclase phenocrysts are generally distinctly visible, thus permitting identification of the rock in the field.

Dacite overlies and in places may intrude the Milltown Andesite in the Goldfield district. The dacite contains sparse lobate quartz phenocrysts that tend to occur in clusters. The largest plagioclase crystals are about 5 mm in diameter. Much of the dacite, like the Milltown Andesite, is highly altered, but, as noted previously, the habit of the phenocrysts enables one to distinguish the two rocks in all but the most extremely altered specimens. Thin sections reveal that biotite, hornblende, augite, and pigeonite are also present in the dacite. Calcite, chlorite, fine white mica, and black opaques are alteration products in the least altered facies. The dacite and Milltown Andesite are the principal host rocks for the gold lodes of the Goldfield district and appear to be the youngest rocks that have undergone alteration.

A unit called dacite vitrophyre by Ransome (1909a, p. 61) unconformably overlies the Milltown Andesite and also, presumably, the dacite in the southern part of the Goldfield district. It is a biotite-rich welded ash flow. The Meda Rhyolite (Ransome, 1909a, p. 65) is another biotite-bearing welded ash flow similar to the dacite vitrophyre in many respects but much less extensive and probably younger (R. P. Ashley, oral communication, 1969). On the map (pl. 1), these contiguous units are shown together as "welded ash flows." Typical dacite vitrophyre is light greenish gray with darker greenish splotches, and has conspicuous biotite flakes 1 to 2 mm across. Quartz phenocrysts are sparse and feldspar phenocrysts moderately abundant. A sample of dacite vitrophyre collected by H. R. Cornwall from a locality just southeast of the Goldfield district gave a potassium-argon age on biotite of 21 million years.

The Chispa Andesite overlies and, according to Ransome (1909a, p. 64), is intercalated with the dacite vitrophyre southeast of the Goldfield district. Only a very small area of Chispa is exposed in Esmeralda County. According to Ransome, it is an ordinary glassy augite andesite with no special features.

The Siebert Tuff (Ransome, 1909a, p. 66) overlies the dacite vitrophyre and older rocks, probably unconformably, west and south of the Goldfield district. The lithology of the Siebert is varied, but it is dominantly tuffaceous volcanic rock. Ransome (1909a, p. 66) lists bedded tuffs, pumiceous ash, conglomerates, and diatomaceous earth as lithologic components and gives a minimum thickness of 500 feet for the formation. Interlayered in the Siebert Tuff is a basalt flow about 100 feet thick and named by Ransome (1909a, p. 69) the Mira Basalt. The name Siebert Tuff is used in the Goldfield area although we have some reservations about the correlation of this unit with the type Siebert of the Tonopah area (Ransome, 1909a, p. 66).

In the Montezuma Range and Clayton Ridge a large area of rhyolitic air-fall tuff and tuff breccia appears to be stratigraphically continuous with the Siebert Tuff. The tuff unit, which rests on pre-Tertiary rocks, is locally at least a thousand feet thick in the Clayton Ridge area east of Clayton Valley. Locally, bedding is distinct, and over much of the area of outcrop dips are at very low angles. However, on Montezuma Peak, dips as high as 25° – 30° were observed. Between Montezuma Peak and Clayton Ridge a layer of fine-grained tuffaceous shale is interbedded with the pyroclastic rocks (pl. 1).

An andesite flow that surrounds Mount Jackson (pl. 1) seems to be intercalated with bedded tuff that probably correlates with the Siebert Tuff. The source of this andesite may be a small pluglike mass of andesite exposed in a canyon bottom just east of the andesite flow. On Mount Jackson and northeast and east of it, a number of bodies of rhyolite intrude and (or) overlie the bedded tuff. How many of these rhyolite bodies are flows and domes and how many are merely isolated remnants of a once continuous lava flow could not be determined. Certainly some, including the rhyolite capping Mount Jackson itself and a mass of brecciated rhyolite about 3 or 4 miles east of the mountain, are intrusive plugs or domes. The rhyolite bodies typically have a perlitic base several tens of feet thick that grades upward into highly spherulitic rhyolite that commonly has abundant vugs and lithophysae several inches across lined with botryoidal chalcedony.

Tilted beds of the Siebert Tuff are overlain unconformably in the western part of the Goldfield district by the Pozo Formation (Ransome, 1909a, p. 70) and the Spearhead Member of the Thirsty Canyon Tuff (Noble and others, 1964). The Pozo, where exposed south of the town of Goldfield, lies beneath the Spearhead Member and consists of fluviatile conglomerate and sandstone derived from volcanic rocks (Ransome, 1909a, p. 70). However, west of the mesa capped by Malpais Basalt (pl. 1) is a large outcrop area of very loosely cemented conglomerate that lies at the same stratigraphic position as the Pozo but which in contrast to the Pozo is made up entirely of pre-Tertiary rock clasts. Nevertheless, because of its identical stratigraphic position and general physical character, it is correlated with the Pozo Formation and considered to be of fluviatile origin. Maximum thickness of the Pozo Formation may be as much as 200 feet. Weakly cemented conglomerate and sandstone on the north slope of Mount Jackson Ridge may correlate with the Pozo Formation.

The Spearhead Member of the Thirsty Canyon Tuff (Noble and others, 1964) was originally named the Spearhead Rhyolite by Ransome (1909a, p. 71). It is a dark-colored welded ash flow that is generally flat lying though faulted and has a maximum thickness of about 80 feet west of Goldfield where it caps buttes and mesas. The Spearhead is the second lowest of seven members of the Thirsty Canyon Formation (Noble and others, 1964, p. D24; Noble and others, 1968), which was derived from a caldera at Black Mountain about 50 miles southeast of Goldfield. According to Noble and others (1964, p. D25), sanidine collected from the lower part of the Spearhead Member has yielded a K-Ar age of 7.5 million years. The Trail Ridge Member of the Thirsty Canyon Tuff, which overlies the Spearhead Member, is also locally present in the vicinity of Goldfield but was not distinguished in the present mapping.

In the Montezuma Range a dense dark rhyolitic or rhyodacitic rock lies unconformably in places on the large air-fall tuff and tuff breccia unit (pl. 1). It is likely that it also lies stratigraphically above the Pozo Formation, but these two units were not found in contact. The rhyolitic rock in many places is an agglutinate, which indicates that its source was very close, probably in the Montezuma Range. The rhyolite is thought to be about the same age or slightly older than the Thirsty Canyon Tuff.

A thin discontinuous layer of sandstone and local conglomerate called Rabbit Spring Formation by Ransome (1909a, p. 71) locally overlies the Thirsty Canyon Tuff west of Goldfield. The unit covers too small an area to be shown on plate 1 and is not differentiated from the overlying Malpais Basalt. The Malpais is a dark olivine basalt about 100 feet thick that caps a broad mesa west of Goldfield and occurs as remnants of what Ransome (1909a, p. 72) believes was once an extensive flow at various other localities in the vicinity of Goldfield (pl. 1). It is not known whether the Malpais is of Tertiary or Quaternary Age.

Tonopah Area

The Tonopah area, as used here, is bounded on the east and northeast by the county line, and on the north, west, and south by alluvium (pl. 1). It thus includes the volcanic hills adjacent to Tonopah on the southwest as well as the terrain southward about half way to Goldfield.

The oldest rocks in this area are possibly the welded and nonwelded ash flows that crop out in the extreme southern part, south of the small outcrops of Paleozoic rocks in the Southern Klondyke mining district. These ash flows are characterized by abundant feldspar and quartz crystals, and lie directly on Paleozoic rocks. Their relation to Tertiary volcanic rocks to the north near Tonopah is not clear.

The oldest Tertiary unit within Esmeralda County and north of the Paleozoic rocks of the Southern Klondyke mining district is the Fraction Breccia, a welded ash flow several hundred feet thick composed of rhyolite and quartz latite. It is readily distinguished by the large number of lithic (mainly andesitic) fragments that it contains. At Tonopah (Nye County) it lies beneath a sedimentary unit, the Siebert Tuff, and lies on the Mizpah Trachyte, the major host rock for the ore deposits in that district.

The Fraction Breccia is the host rock for lode deposits of silver in the Divide mining district, and it is more or less altered throughout the Tonopah area. Ian Campbell, who made a petrographic study of the rocks of the Tonopah district, says of the Fraction Breccia (Nolan, 1935, p. 27):

> "The matrix is light colored, extremely fine grained, and under the microscope appears holocrystalline to hypocrystalline. Fluidal texture has been observed. The aggregate index is lower than canada balsam and higher than gamma of sanidine. Phenocrysts of quartz and sanidine are abundant, and there are a few of albite and biotite. The sanidine is generally much altered to calcite, the albite somewhat altered to sericite, the biotite also to sericite. There has been some silicification throughout the rock and heavy kaolinization locally. Pyrite, partly altered to limonite, occurs sparingly."

Geologists working at the Nevada Test Site and in the bombing and gunnery range north of the Test Site have correlated the Fraction Breccia with an ash flow unit in the Kawich Range that is more than 7,000 feet thick and has yielded a K-Ar age of 17.5 million years (R. E. Anderson and E. B. Ekren, oral communications, 1964).

The Siebert Tuff, consisting of tuff, tuffaceous shale, diatomite, and conglomerate, overlies the Fraction Breccia. The formation dips westward at a low angle, but locally around pluglike intrusions of rhyolite or quartz latite it is tilted up to high angles and in places even steeply overturned. The minimum thickness of the unit is 600 feet west of Tonopah (Spurr, 1905, p. 53). Its finely stratified character and the nature of its lithology indicates a lacustrine origin. Radiometric K-Ar ages determined for the Fraction Breccia (17.5 million years) and the Brougher Dacite (16.2 million years), which intrudes the Fraction and Siebert, fix the age of the Siebert between 16.2 and 17.5 million years. Thus it is considered Miocene and significantly older than the 10.5- to 12.7-million-years-old sedimentary beds in the Cedar Mountains, Silver Peak Mountains, and Fish Lake Valley formerly referred to as the Esmeralda Formation and thought to be correlative with the Siebert.

Discrete bodies of fluidal rhyolite, which is probably correlative with the Oddie Rhyolite at Tonopah (Spurr, 1905, p. 49), occur between Tonopah and the South Klondyke district (pl. 1). The rhyolite occurs mostly as plugs that intrude the Fraction Breccia and Siebert Tuff; some of the pluglike masses appear to be cumulo-domes formed as the viscous lava mushroomed out upon reaching the surface. In the Southern Klondyke mining district the rhyolite also forms dikes in Paleozoic rocks. The rhyolite is nearly white and contains fairly abundant small phenocrysts of quartz and sanidine in an aphanitic groundmass. In many places it has a well-defined flow banding, and adjacent to contacts with the intruded Siebert Tuff it commonly has a glassy selvage several feet thick.

Andesite crops out in the Divide district (Divide Andesite) about 5 miles south of Tonopah, and at various places in the South Klondyke district and farther south (pl. 1). An elongate body of andesite also crops out about 2 miles west of Tonopah. The Divide Andesite is described by Knopf (1921, p. 155) as a "gray porphyritic rock carrying numerous crystals of glassy striated feldspar and biotite." In various places it weathers like a horizontally bedded or vertically bedded rock. It intrudes the Fraction Breccia and the Siebert Tuff, but its age relation to the Oddie Rhyolite is not clear. The Divide Andesite is fairly well altered and in places brecciated, especially near contacts.

The andesite in the southern part of the Tonopah area is darker and fresher looking than the Divide Andesite. It occurs clearly as lava flows that may be in part basaltic. However, one specimen shows thin section characteristics virtually identical to the Milltown Andesite of Goldfield.

Plugs, cumulo-domes, and flows of quartz latite and felsite are conspicuous among the volcanic rocks of the Tonopah area. Mount Butler, just south of Tonopah, as well as other prominent hills, are composed of this rock. Some of the rocks here included in this unit were called the Brougher Dacite by Spurr (1905, p. 44). However, thin sections show that K-feldspar is about as abundant as plagioclase (andesine) in this rock, so that quartz latite is a petrographically more accurate rock name. Other mineral constituents besides feldspar include quartz, biotite, black opaques, and rarely hornblende and (or) augite. The groundmass of the Brougher quartz latite is generally glassy. The age relation between these quartz latites and the Oddie Rhyolite described above is not certainly known.

Other quartz latitic rocks in the Tonopah area include very dark dense lithoidal rocks that from a distance have the general aspect of basalt. This variety of quartz latite definitely overlies the Divide Andesite. Nearly all varieties of quartz latite in the Tonopah area contain biotite as the principal ferromagnesian mineral. In some places, as east of the Divide mining district 5 miles south of Tonopah, the rock is somewhat altered, calcite being the main alteration mineral.

Olivine basalt caps various hills a few miles west and south of Tonopah. It overlies at least one variety of quartz latite south of Tonopah and is inferred to be the youngest volcanic rock in the area. As previously noted, some of the rock shown as andesite in the southern part of the Tonopah area has basaltic aspects and may actually be more accurately referred to as basalt.

Monte Cristo Range and Cedar Mountains

These areas, in the northern part of the county, were mapped by Ferguson and others (1953, 1954), and only four days were spent during 1963 reconnoitering the area, with the main objective of relating the stratigraphic section to sections exposed elsewhere in the county.

The lowest Tertiary unit in the area is a series of welded ash flows exposed in the Cedar Mountains in the extreme northeast part of the area (the older lavas of Ferguson and others, 1953). No petrographic study was made of these ash flows, but hand specimens show that they are rich in biotite and fairly silicic, probably in the quartz latite or perhaps rhyolite composition range. In the vicinity of Crow Springs (pl. 1) these welded ash flows dip as steeply as 70° W., but farther northwest, in the Cedar Mountains, dips are much more gentle and amount to no more than 10° in the western part of the range. The thickness of the unit in the Crow Springs area may be as much as 3,000 feet.

Although the welded ash flows in the Monte Cristo Range-Cedar Mountains area occupy the basal part of the Tertiary section, as the welded ash flows of Miller Mountain and the northern end of the Silver Peak Mountains, they are lithologically dissimilar and apparently were derived from a different source.

In the western Cedar Mountains the welded ash flows are overlain by a rhyolite breccia. Farther south and west in the Monte Cristo Range this volcanic breccia, which Ferguson and others (1953) referred to as a pyroclastic unit in the lower part of the Esmeralda Formation, directly overlies Paleozoic and Mesozoic basement rocks, the welded ash flows found in the Cedar Mountains being absent. The volcanic breccia unit is probably less than 1,000 feet thick and consists dominantly of quartz porphyry fragments a few inches to more than a foot in diameter in a matrix also consisting of quartz porphyry. Very locally this breccia grades into a rock with all the aspects of a welded ash flow, and it seems likely that the unit may in fact be a unique relatively local facies of a welded ash flow. Ferguson and others (1953) note that the lower part of this pyroclastic unit contains abundant fragments of older rocks, and he correlates the unit with the Fraction Breccia of the Tonopah area.

Shale, siltstone, sandstone, limestone, and tuff that Ferguson and others (1953) have called Esmeralda Formation, a practice not followed here, overlie the rhyolite breccia. Dips in these beds as high as 40° were observed in the Cedar Mountains, and locally a few miles northeast of Coaldale, the beds are tightly folded along axes trending N. 50°–60° W.

Ferguson and others (1953) regard the Tertiary sedimentary sequence in the Monte Cristo Range and Cedar Mountains as Miocene and lower Pliocene based on mammalian fossil collections from similar rocks in nearby localities. This age designation has been substantiated recently by two potassium-argon dates on a tuff bed 200 to 250 feet above fossil-bearing strata near "Tedford Pocket" on the east side of the Cedar Mountains a few miles north of Esmeralda County (Evernden and others, 1964, p. 177, 180). A potassium-argon age on biotite gave 10.7 million years, and a K-Ar date on sanidine gave 11.5 million years. Both of these dates fall within the Clarendonian on the mammalian time scale.

Rhyolite plugs, domes, and flows that Ferguson and others (1953) correlate with the Oddie Rhyolite near Tonopah intrude and overlie the sedimentary rocks described above in the central and eastern parts of the Monte Cristo Range (pl. 1). Where contacts are exposed the shaly sedimentary rocks are commonly upturned and in places contorted near the rhyolite contact. It appears that the fluidal rhyolite intruded the sedimentary rocks as plugs, and that many of these broke through to the surface, where they mushroomed out to form cumulo-domes and small, locally interconnecting flows. Inasmuch as the rhyolite cuts early Pliocene sedimentary rocks, its age is fixed as not older than early Pliocene. It seems likely that the rhyolite in the Monte Cristo Range-Cedar Mountains area is younger than the Oddie Rhyolite near Tonopah.

The highest parts of the arcuate Monte Cristo Range are covered by andesitic rocks having feldspar as a phenocrystic mineral. Ferguson (1928, p. 135) first described this unit and later Ferguson and others (1953) named it the Gilbert Andesite. Ferguson (1928, p. 135) noted that a considerable period of erosion must have intervened between eruption of the Oddie Rhyolite and the andesite. The andesite is unaltered and flat lying, in contrast to the tilted older sedimentary rocks and flows, thus indicating fairly strong deformation sometime during the Pliocene before eruption of the andesite. The distribution of the Gilbert Andesite indicates that it was derived from vents in the central part of the Monte Cristo Range. The precise age of the Gilbert Andesite is not known, although it is almost certainly older than Pleistocene and can be no older than early Pliocene. An apparently anomalously old date of 15.1 million years was obtained from the Gilbert Andesite by K-Ar methods (table 3).

Erosion remnants of basalt flows crop out in the northern part of the Monte Cristo Range. Ferguson and others (1953) state that the basalt was extruded after the ranges had attained approximately their present form. The absence of scoria cones and volcanoes in the northern part of Esmeralda County indicates that the flow remnants represent basalt derived from outside the county, most likely from sources to the west where basalt volcanic centers are conspicuous (Ferguson and others, 1953). The age of the basalt is not known, but it is most likely late Pliocene or Pleistocene.

Weepah Hills, Lone Mountain, and Northeastern Part of Clayton Valley

The bulk of the Tertiary rocks in the western part of the Weepah Hills (pl. 1) consists of shale, siltstone, sandstone, and tuff of the lacustrine Esmeralda Formation. Interfingering volcanic rocks, including tuff, basalt, rhyolite, and ash flows are of relatively small extent. The Esmeralda Formation in the western Weepah Hills is in a very general way lithologically similar to and possibly continuous under alluvial cover with the sedimentary sections east of Coaldale and in the Monte Cristo Range on the one hand, and to the section exposed in the eastern part of Clayton Valley on the other. If the sections are actually equivalent and continuous, which cannot be proved on the basis of information presently available, a depositional basin having a minimum length of 40 to 50 miles and a width of at least 20 miles would be indicated. A basin of this size would be of an order of magnitude similar to that conceived by Turner (1900, p. 198) as the depositional site of his Esmeralda Formation.

Although most of the sedimentary rocks in this part of the county probably range from 10 to 12.5 million years, some, including those beneath the basalt that caps The Monocline (pl. 1), are younger. A tuff bed in the area of The Monocline has yielded a potassium-argon age of 6.9±0.3 million years (Richard Moiola, oral communication, 1966). Thus the age of the Esmeralda Formation is late Miocene to late Pliocene.

Ash flows are sparse in this part of the county. A nonwelded ash flow deposit is interlayered with the Esmeralda Formation in the extreme southwest part of the Weepah Hills (pl. 1) and a welded ash flow crops out in the Foothills northeast of Lone Mountain. The stratigraphic position of this welded ash flow in the sedimentary sequence is uncertain. It is arbitrarily placed lower in the section on the assumption that it may be correlative with the section of ash flows in the Cedar Mountains area. A rhyolite plug or flow in the southern part of the Weepah Hills intrudes the Esmeralda Formation and is regarded as the same age as other rhyolitic rocks in the northern and eastern part of the county.

Basalt of two ages is present in the Weepah Hills area. That which caps the Esmeralda Formation on The Monocline (pl. 1) is of late Pliocene or early Pleistocene Age as is most of the other basalt in the county. However, the basalt forming the conspicuous cinder cone and small flows just southwest of Weepah Hills in the extreme northwestern corner of Clayton Valley appears to be younger than some of the Quaternary alluvium and is considered to be of late Pleistocene or Holocene Age.

Silver Peak and Palmetto Mountains

The thickest section of Tertiary rocks is exposed in the Silver Peak Mountains, and some of the same units extend into the Palmetto Mountains. The section in the Silver Peak Mountains is pieced together in part from inferred relationships as some units are restricted to only a small part of the range, and their stratigraphic position with respect to units of similarly restricted outcrop area exposed elsewhere in the range cannot be observed.

The oldest Tertiary rocks are the lower nonwelded and lower welded ash flows in the northern part of the range (pl. 1). These ash flows lie unconformably on pre-Tertiary rocks, and biotite from them has yielded a potassium-argon age of 21.5 million years (i.e., fairly early Miocene) (Robinson and others, 1968, table 1). Quartz, sanidine, plagioclase, and biotite crystals and clasts up to 2 mm in diameter make up 15 to 20 percent of the ash flows, which are probably correlative with those in the Volcanic Hills and Miller Mountain.

In the central part of the Silver Peak Mountains, the ash flows described above are absent, and the oldest Tertiary rock is sedimentary unit 1, conglomerates or fanglomerates made up entirely of Paleozoic rocks. These conglomerates, which are commonly red or green and locally range to shades of dark purple, crop out on the eastern and western flanks of the range. The largest area of outcrop is just south of Mineral Ridge (pl. 1), where Robinson (1964) and Robinson and others (1968, fig. 9) have estimated a thickness of over 5,600 feet. On the western flank of the range the same unit crops out in scattered localities and has a maximum thickness of only a few tens of feet. Within the conglomerates on the east side of the range are at least three large blocks of probably Precambrian dolomite breccia as much as several hundred feet in maximum dimension. Apparently these are landslide blocks incorporated in the conglomerate during its formation. The coarse, poorly sorted character of the conglomerates, their highly restricted distribution, and their composition indicate that they are probably fanglomerates of local origin, derived from a nearby highland of pre-Tertiary rocks. A camel bone collected by Paul T. Robinson from near the base of the thick conglomerate body on the east flank of the range was identified as either *Megatylopus* sp. or *Aepycamelus* sp. by S. David Webb (Robinson and others, 1968, fig. 9 and p. 606). Its age is probably Clarendonian or Hemphillian (Pliocene) but may be as old as Barstovian (late Miocene), the age herein assigned to it.

Overlying sedimentary unit 1 is a thick volcanic breccia locally containing interlayered flows and lenses of tuffaceous sandstone. The overall composition is andesitic but local phases may approach the composition of dacite. The breccia crops out at intervals along a belt up to 3 miles wide extending from the eastern part of the Palmetto Mountains to the vicinity of Icehouse Canyon in the Silver Peak Mountains, a distance of about 30 miles. A similar andesitic breccia crops out on the eastern flank of the White Mountains, so that the overall outcrop length of the unit is probably close to 50 miles. The breccia consists of blocks of dark andesitic rock from a few inches to as much as 2 or 3 feet in diameter in a soft matrix of lighter color. Interlayered lenticular flows are lithologically identical to the blocks and are commonly a few tens of feet thick and a few hundred yards in strike length. The monolithologic nature of the breccia and the intercalated stubby flows of the same composition suggest that the breccia is a flow breccia derived from either a series of vents or possibly a fissure extending along the north flank of the Palmetto Mountains and northwestward through the Silver Peak Mountains.

The volcanic breccia is overlain unconformably on the western flank of the Silver Peak Mountains by sedimentary unit 2, probably the most extensive Tertiary sedimentary unit in the Silver Peak Mountains and possibly in the entire county. This unit, which consists of tuffaceous shale and sandstone, tuff, and fine conglomerate, can be traced more or less continuously across the range to the eastern flank south of Mineral Ridge where it unconformably overlies the conglomerate composed of pre-Tertiary rocks. A welded ash flow occurs within sedimentary unit 2 on the western flank of the Silver Peak Mountains.

Sedimentary unit 2 contains some fresh-water fossils, plant remains, and bone fragments but cannot be closely dated in the Silver Peak Mountains on fossil evidence. It is inferred, although outcrops are not continuous, that sedimentary unit 2 correlates approximately in time of formation with sedimentary rocks in the Coaldale area, and in the Monte Cristo Range-Cedar Mountains, Weepah Hills, and the north end of Fish Lake Valley (pl. 1). Radiometric K-Ar ages available for these various units include one of 12.7 million years on a sample from low in the Tertiary section in the Coaldale area (Evernden and James, 1964, p. 970); 10.7 and 11.5 million years on samples from two beds in the Cedar Mountains (Evernden and others, 1964, p. 177, 180), and 11.1 and 11.4 million years on samples from two beds in the northern part of Fish Lake Valley (Evernden and others, 1964, p. 177, 179). It is tempting to believe, as Turner did (1900, p. 198), that these various areas of sedimentary rocks were all formed in one continuous basin of deposition. Although this concept cannot be ruled out, the marked variations in lithology from place to place suggest instead that a number of smaller lakes or basins were the recipients of sedimentary deposits in late Miocene and early Pliocene time.

Closely interrelated rhyolitic air-fall tuff and rhyolitic flows, domes, breccias, and intrusive masses rest on or intrude sedimentary unit 2 in some places and on pre-Tertiary rocks elsewhere. The tuff is, in general, poorly bedded although locally bedding is distinct. Thickness is extremely variable from a few tens of feet in the southern part of the range to possibly 1,200 to 1,500 feet on Rhyolite Ridge. The tuff consists mainly of poorly sorted lapilli and vitric tuff. It is 6.0 million years old on the basis of a K-Ar date by E. H. McKee (Robinson and others, 1968, table 1). Interlayered with the tuff, and locally intruding it, are rhyolite flows, domes, breccias, and intrusive masses. The rhyolite is typically dense fine-grained rock much of which shows good flowage banding. Phenocrysts are rare.

The rhyolitic air-fall tuff and rhyolite flows, domes, breccias, and intrusive masses are overlain by a large mass of porphyritic latite or trachyandesite which is at least 500 feet thick. It is a gray, grayish-green, or reddish rock characterized by abundant large plagioclase and sanidine phenocrysts in roughly equal proportions. Feldspar crystals as large as 5 or 6 mm across are common. Biotite, in books as large as 4 mm across, form 5 to 10 percent of the rock. Some cliff outcrops of the porphyritic latite show a crude layering on a gross scale. Locally sandstone, conglomerate, and tuff are interlayered with the latite flows. The porphyritic latite is 5.9 million years old on the basis of a K-Ar date by M. A. Lanphere (Robinson and others, 1968, table 1). On the east flank of the Silver Peak Mountains, andesite locally occurs in association with the porphyritic latite and may in part be intrusive.

The distribution, thickness, and lithologic character of the rhyolitic air-fall tuff, of the rhyolitic flows, domes, breccias, and intrusive masses, and of the porphyritic latite or trachyandesite suggest that the central part of the Silver Peak Mountains may have been a calderalike structure. The rhyolitic tuff is a thick unit of relatively restricted distribution suggesting that it was derived from a vent in the immediate vicinity. The rhyolite flows, domes, breccias, and intrusive masses form a discontinuous belt of outcrop peripheral to the large mass of porphyritic latite and perhaps were emplaced near or along the rim of the calderalike structure. The porphyritic latite or trachyandesite was largely confined within the caldera. Robinson (1968) and Robinson and others (1968, p. 604–605, pl. 1) have also concluded that a caldera is present in this area.

In the area near Piper Peak in the west-central part of the Silver Peak Mountains, the porphyritic latite is overlain by porphyritic basalt, an olivine-hypersthene-augite basalt. On our preliminary map of the county (Albers and Stewart, 1965), this basalt was shown as a part of a unit considered to be the stratigraphically highest unit in the area. Detailed work by P. T. Robinson (Robinson and others, 1968, p. 605 and pl. 1) has shown, however, that our unit contains two basalts; the lower one (Tertiary) is older than several other volcanic units as well as a sedimentary unit in the area; the upper one (Tertiary or Quaternary), however, is the highest volcanic unit in the Silver Peak Mountains.

In an area about 3 miles southeast of Piper Peak, the porphyritic basalt is overlain by a unit we designate the upper welded ash flow. This ash flow has a total outcrop area of only 2 or 3 square miles and was not recognized elsewhere in the county. Its mineralogic composition is quite similar to the porphyritic latite, and it seems likely that it came from the same vent. The rock is rich in biotite, and plagioclase phenocrysts slightly exceed K-feldspar in abundance. Augite is also present as phenocrysts, and in places lithic fragments of andesite were seen. The rock shows good eutaxitic structure. A radiometric age of 6.1 million years has been determined by E. H. McKee for this welded ash flow unit (*in* Robinson and others, 1968, table 1). This age is slightly older than that of the underlying porphyritic latite (5.9 million years) and lower rhyolitic tuff (6.0 million years), but all these dates are the same within the limits of accuracy of the methods, and the three units can be considered to be virtually synchronous.

Sedimentary unit 3 is restricted to a narrow elongate structural basin west of Rhyolite Ridge. A unit cropping out in a small area 5 miles west of Piper Peak may also be correlative. West of Rhyolite Ridge the sedimentary unit overlies the rhyolitic air-fall tuff and west of Piper Peak the possibly correlative unit overlies the porphyritic basalt or, where this basalt is absent, it overlies the rhyolitic air-fall tuff. The age relationships of sedimentary unit 3 and the upper welded ash flow southeast of Piper Peak are uncertain because the units do not occur in contact with one another. Sedimentary unit 3 west of Piper Peak, however, contains clasts possibly derived from this welded tuff and the sedimentary unit is thus considered younger than the welded tuff. Sedimentary unit 3 consists predominantly of claystone and shale but includes also sandstone, grit, thin tuff beds, and fresh-water limestone. In 1963, the Stauffer Chemical Co. drilled a hole 1,453 feet deep through this unit near Cave Spring near the southeast corner of sec. 27, T. 1 S., R. 37 E., west of Rhyolite Ridge. The true thickness of the sedimentary unit penetrated in the drill hole is about 1,300 feet.

Tertiary or Quaternary rocks in the Silver Peak-Palmetto Mountains area include two units, basalt and sedimentary unit 4. Although these two rock units are not in direct contact, it is inferred that the basalt is older, as pebbles of basalt were seen in the conglomerate of sedimentary unit 4. However, weakly consolidated sediments of the same general nature underlie basalts in several places elsewhere in the county. Most of the basalt, which occurs locally in the Silver Peak Mountains, is olivine-augite basalt; however, augite basalt and hornblende basalt are also present locally. It is inferred that the basalt as well as the younger(?) sedimentary unit are late Pliocene or Pleistocene. An age of 4.8 million years was obtained by K-Ar methods from one of these basalts in the western part of the Silver Peak Mountains (Robinson and others, 1968, table 1).

Sedimentary unit 4 includes weakly consolidated conglomerates and tuffaceous rocks well over 1,000 feet thick that crop out east of Fish Lake Valley in the central and northern part of the Silver Peak Mountains.

White Mountains, Volcanic Hills, North End of Fish Lake Valley, Miller Mountain, and Candelaria Hills

The Tertiary system is represented in this most western part of the county by nonwelded and welded ash flows, andesite and andesitic breccia, tuffaceous sedimentary rocks, quartz latite flows, clastic sedimentary rocks, diatomite, and basalt in roughly ascending order.

The oldest unit is in the Volcanic Hills and consists of a lower nonwelded ash flow including in places some possible air-fall tuff. This unit in the Volcanic Hills is overlain by a unit of welded ash flows that appear in hand specimen to be similar to tuffs in the Miller Mountain and Candelaria Hills area and to welded tuffs at the extreme north end of the Silver Peak Mountains. On the basis of K-Ar age determination (Robinson and others, 1968, table 1), one of these welded tuffs in the southern part of the Miller Mountain area is 22.8 million years old and the possibly correlative rocks at the north end of the Silver Peak Mountains are 21.5 million years old.

Volcanic breccia of andesitic or dacitic composition crops out in a small area north of Dry Creek in the northern part of the White Mountains. This unit is lithologically similar and very likely correlative with a widespread volcanic breccia in the central part of the Silver Peak Mountains and on the north flank of the Palmetto Mountains. A few small outcrops of porphyritic andesite, which are probably related to the volcanic breccia unit, crop out 3 miles north of Dry Creek.

A lower sedimentary unit crops out extensively in the Volcanic Hills, in the northern part of Fish Lake Valley, and in the northern part of the White Mountains. This unit contains some interlayered well-bedded tuff. Evernden and others (1964, p. 177, 179) collected two samples of crystal vitric tuffs interlayered in this tuffaceous sedimentary unit from near the center of T. 1 N., R. 35 E. (see pl. 1), and determined by K-Ar methods the ages of the contained biotites. One biotite was from a tuff bed just below a micromammal level and yielded an age of 11.4 million years. The other biotite, from a tuff bed 25 feet above the micromammal level, yielded an age of 11.1 million years. Both of these dates fall within the Clarendonian on the mammalian scale.

The area of quartz latite flows, plugs, and cumulo-domes that overlies, intrudes, and is partly interlayered with the lower sedimentary unit on the extreme northeast flank of the White Mountains (pl. 1) covers at least 40 to 50 square miles within the county and also crops out over a large area in adjacent Mineral County. Several individual domes and plugs were recognized in the field during reconnaissance mapping, and it is probable that the quartz latite in this large area came from many individual vents. The quartz latite ranges from pale red to light gray and from nonbanded to well banded. Phenocrysts, which are mostly quartz and oligoclase, range from sparse to abundant in various facies. Biotite is present in some but not all facies. K-feldspar was not recognized in phenocrystic form, but the sodium cobaltinitrite stain test indicates that it is abundant in the groundmass.

The large area of nonwelded ash flows centering around hill 6001 in the northern part of Fish Lake Valley (pl. 1) dips very gently east and is clearly underlain on the west by the 11+ million-year-old lower sedimentary unit described previously and overlain on the east by an upper sedimentary unit of shale, siltstone, sandstone, limestone, and fine conglomerate. These latter rocks crop out west of the Fish Lake Valley playa and are probably correlative with sedimentary unit 3 in the Silver Peak Mountains.

Tertiary or Quaternary rocks include diatomite and weakly lithified sandstone and conglomerate. The sandstone and conglomerate unit, which crops out near U.S. Highway 6 near the western edge of the county, is clearly older than the Pliocene or Pleistocene basalt of the area; the diatomite appears in the main to be older than the basalt, but may in part be younger. The basalt covers extensive parts of the Volcanic Hills and the northeast flank of the White Mountains; the greatest thickness of basalt is probably on Davis Mountain. The source of the basalt is not known. The diatomite, the sandstone and conglomerate, and the basalt are probably all very late Pliocene or possibly Pleistocene, but definitive age data are not available.

Slate Ridge and Southern End of County

The Tertiary system is represented in the southern part of Esmeralda County entirely by volcanic rocks with the possible exception of some local gravels capped by basalt that may be either Tertiary or Quaternary. The oldest Tertiary rocks are beds of air-fall tuff and nonwelded ash flows that lie at the base of a sequence of welded ash flows, the Timber Mountain Tuff, at least 1,350 feet thick. These units are very well exposed in a series of fault blocks between the eastern part of Slate Ridge and Grapevine Canyon (pl. 1). The whole sequence of air-fall nonwelded and welded tuff is believed to be correlative with the Ammonia Tanks Member of the Timber Mountain Tuff in the Nevada Test Site east of Esmeralda County. Potassium-argon radiogenic ages ranging from 10.5 to 11.5 million years for the Ammonia Tanks Member have been determined by R. W. Kistler of the U.S. Geological Survey. The welded ash flows have the composition of a biotite quartz latite, with quartz, sanidine, plagioclase, and biotite forming the phenocrystic minerals. A little augite and sphene are also present. As may be seen on the geologic map (pl. 1), the ash flows apparently spilled northward into Oriental Wash through a gap in Gold Mountain.

The oldest Tertiary rocks in the Grapevine Mountains at the extreme southern end of the county are welded ash flows that are part of the Timber Mountain Tuff. The ash flows here are overlain by a fairly light-colored dacite that locally shows steep flow banding. The rock contains moderately abundant plagioclase (An_{45-50}) and very subordinate biotite phenocrysts. Although no quartz phenocrysts were seen, the rock is considered more likely to be dacite than andesite because of its comparatively light color.

Around the eastern end of Slate Ridge the Spearhead and possibly Trail Ridge Members of the Thirsty Canyon Tuff form cappings on the older welded tuffs. This is the farthest westward extent of the Thirsty Canyon Tuff.

Basalt overlies the welded ash flows north of Grapevine Canyon, and isolated areas of basalt are surrounded by alluvium in the canyon (pl. 1). One vent from which basalt was erupted is only a few hundred yards north of the highway in Grapevine Canyon. The basalt overlies beds of tuff and weakly cemented gravel and sand in the western part of Slate Ridge. It is not known whether the basalt is of late Pliocene or of Pleistocene Age.

QUATERNARY DEPOSITS

Deposits formed during the Quaternary include glacial moraines, older alluvium (which may in part be glacial outwash), bedded clay and silt, landslide deposits, desert wash, colluvium, alluvium, and playa deposits. In addition, at least some of the basalts — including, for example, the cone in the northwest corner of Clayton Valley — formed during the Quaternary. Some of the sedimentary deposits described under the Tertiary may also be early Quaternary.

Glacial moraines are found only above about 9,000 feet in the upper reaches of Chiatovich Creek in the White Mountains (pl. 1), where two morainal lobes extend for a mile or so into the county. The relatively small amount of dissection of the moraines suggests that they are very young.

Principal deposits of older alluvium are in the Palmetto Mountains, Weepah Hills, and locally along the west side of Fish Lake Valley. These deposits are dominantly coarse gravel and conglomerate. They range up to more than 100 feet thick, but thicknesses of a few tens of feet are most common. Some of the deposits, as in the White Mountains area, may be glacial outwash.

Part of the valley north of Mount Jackson Ridge (pl. 1) is underlain by flat or nearly flat buff-colored beds of rather weakly lithified bedded clay and silt. The exposed thickness of these beds is several tens of feet and weathering has sculptured them into a miniature badlands topography. From the weak lithification and flat dips it is inferred that this unit is no older than Pleistocene. It may be a dissected playa deposit.

About half a dozen landslide deposits were mapped in the county. Two of these are on the southwest side of Malpais Mesa southwest of Goldfield (pl. 1); others are in the western part of the Silver Peak Mountains and in the White Mountains. Most of these deposits show little or no dissection, and it appears that they are very young.

By far the most abundant Quaternary deposits are grouped under the heading desert wash, colluvium, alluvium, and playa deposits, which includes talus and fan deposits. Approximately 50 percent of the county is covered by this type of material, and in some valleys it has accumulated to depths of many hundreds of feet. It is distinguished from older alluvium by its lack of lithification or consolidation, and also by the fact that, except where recent faulting has occurred, as in Fish Lake and Big Smoky Valleys (pl. 1), it has not been uplifted and dissected. In the mountainous areas some of the larger ravines are floored with alluvial deposits wide enough to be shown on the county geological map.

Playas or mud flats that are covered with shallow water at intervals and which otherwise are covered with a thin crust of salt are present in several of the larger valleys. The largest playa is Columbus Salt Marsh (pl. 1), but large playas are also present in Big Smoky and Clayton Valleys. Smaller playas are in Fish Lake Valley, Alkali Flat, and an unnamed valley in the northwestern part of the county.

STRUCTURE

GENERAL STATEMENT

Esmeralda County lies within a zone of disrupted structure at least 300 miles long and 50 to 100 miles wide that forms a transition between the northwest-trending Sierra Nevada block to the west and the north-northeast-trending ranges of the Great Basin province to the east (fig. 9). Elements of both the northwest and north-northeast trends are prominent in the county, as is also an easterly trend with southward convexity connecting the other two trends. The relation among the trends is shown well in the arcuate Silver Peak-Palmetto-Montezuma range system where the strike of pre-Tertiary sedimentary and igneous units, as well as bedding, fold axes, and faults, changes gradually from N. 45° W. in the Silver Peak Range, to east-west in the Palmetto, to about N. 20° E. in the vicinity of Montezuma Peak (pl. 1). This arcuate bend in pre-Tertiary rocks is reflected by the topography and will hereafter be referred to as the Silver Peak-Palmetto-Montezuma oroflex. (The term "oroflex" (Albers, 1967) refers to a mountain range with an arcuate trend that is supposed to result from tectonic bending of the crust.) Elsewhere in the county the arcuate structures are less complete, being disrupted by younger faulting or partly obscured by Tertiary rocks and alluvium. Slate Ridge forms the east-west part of an arcuate structure south of the Silver Peak-Palmetto-Montezuma oroflex and approximately concentric with it. In the southern and eastern parts of the Weepah Hills the strike of a nearly complete section of Cambrian rocks changes from west-northwest to east, to nearly north, and wraps around the southern and eastern sides of the Lone Mountain and Weepah plutons. This arcuate structure is interpreted to be part of the gross structural pattern (Albers, 1967). A line connecting Mineral Ridge, Goat and Angel Islands, and Paymaster Ridge may be still another arc highly disrupted by faulting. The Monte Cristo Range and Cedar Mountains form a topographic arc, but so much of the pre-Tertiary rock is covered by younger volcanic rocks that it is not clear whether the arcuate pattern reflects the structure of buried pre-Tertiary rocks or is merely incidental to the pattern of volcanic activity. If it is a structural arc or oroflex, it is much disrupted by faulting, as judged by the diverse strikes observed in different outcrop areas.

Cutting the series of arcs that dominate the pre-Tertiary structure of the county are a multitude of high-angle faults having displacements ranging from a few feet to many miles, and low-angle faults or thrusts having unknown amounts of displacement. Most of the major faults are believed to have formed prior to eruption of Tertiary volcanic rocks. The largest faults are strike-slip faults having apparent right-lateral separation. They include a fault along the west side of Fish Lake Valley (the Death Valley-Furnace Creek fault zone) (pl. 1 and fig. 9) with a separation of at least 18 miles within the county and a possible separation of 50 miles farther south in Death Valley; a fault in Soda Spring Valley (Mineral County), which extends into Esmeralda County, with a separation of at least 4 and probably 10 miles (Ferguson and Muller, 1949, p. 14; Nielson, 1965); and a fault along the Cedar Mountains on which the total separation is unknown, but which showed a right-lateral component of rifts formed during a major earthquake in 1932 (Gianella and Callaghan, 1934, p. 16). This latter fault is along a prominent zone of disrupted topography 500 miles long called the Walker Lane by Locke and others (1940), and considered by them to be a structural break of major importance.

A marked contrast in the geology on either side of Big Smoky Valley, as well as the presence of the valley itself, and numerous recent faults along the south side (pl. 1) indicate the existence of an eastward-trending fault of major importance. The Precambrian Wyman and Reed Formations crop out on Lone Mountain south of the valley but do not appear on the north side where the rocks exposed are of Ordovician and Mesozoic Age. The Mesozoic rocks north of Big Smoky Valley form part of the Luning Embayment (Ferguson and Muller, 1949), the south edge of which is thought to have been very close to the position of Big Smoky Valley and Columbus Marsh. West of Columbus Marsh the lithology of a section of Cambrian rocks on Miller Mountain differs markedly from that of the Cambrian section in Volcanic Hills only a couple of miles to the southeast (pl. 1). Still farther west on the same line of strike the Inyo batholith ends abruptly at the north end of the White Mountains. Moreover, neither of the two major faults mentioned earlier — in Fish Lake Valley and

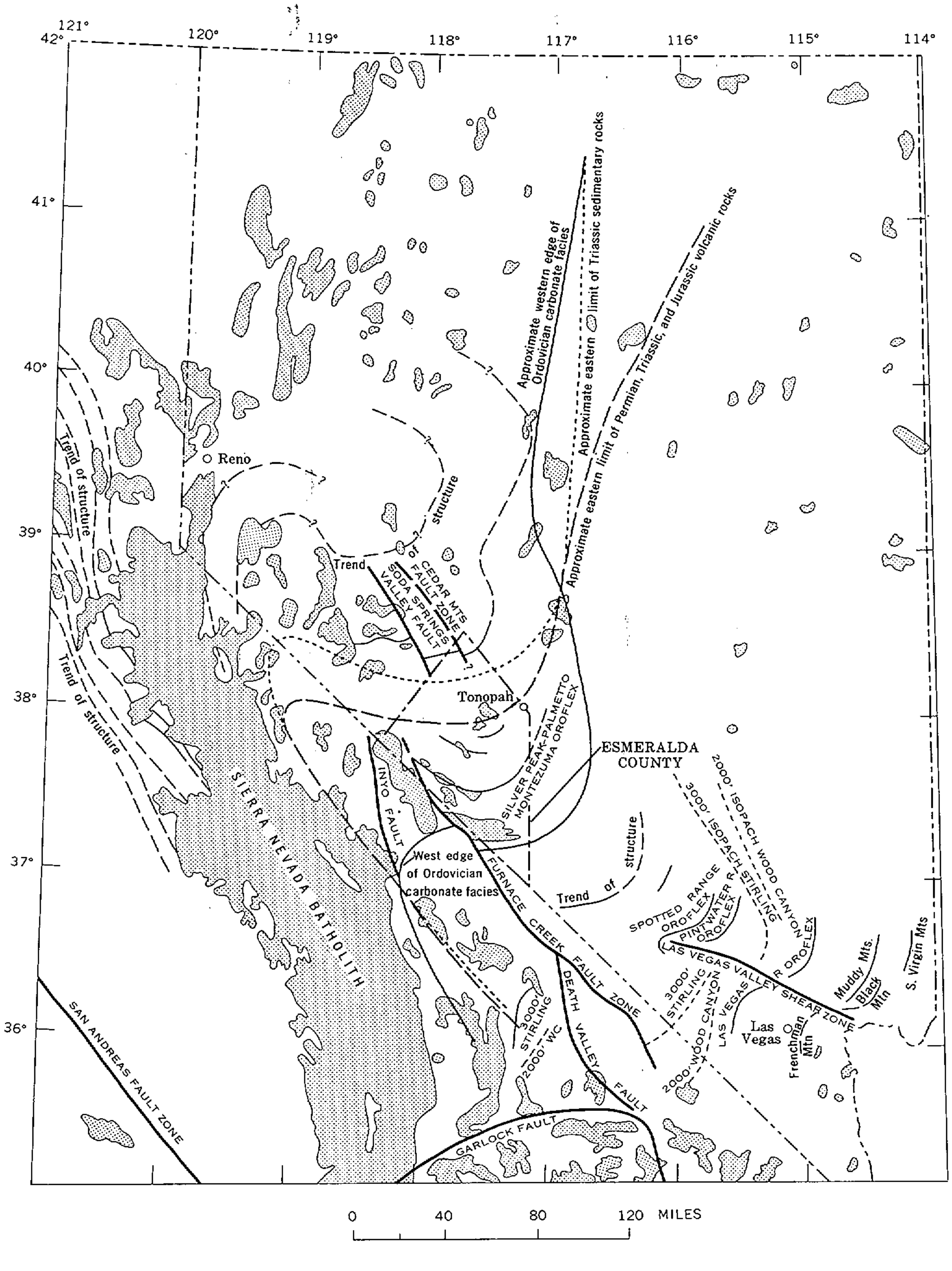

Figure 9. Summary of structural features along the mobile belt east of the Sierra Nevada.

8 0 0 2 2 2 1 1 3

in Soda Spring Valley — could be traced across the zone marked approximately by the 38th parallel, and a possible interpretation is that the two faults in question are one and the same, being offset in the right-lateral sense along an east-west line just north of the 38th parallel (pl. 1).

In addition to the dominantly strike-slip faults noted above there are numerous other large faults in the county. The two main strikes shown by these faults are north-south and east-west. Many of the east-west faults are arcuate, convex toward the south, and are interpreted to have chiefly dip-slip displacement. Chief among these is the fault along the north side of Mount Dunfee, faults along the north side of the Palmettos, and a fault in Paymaster Canyon. All these faults are high-angle faults having stratigraphic separation of several thousand feet, the fault along the north side of Mount Dunfee having a separation of at least 4,000 feet. In general it may be said that these high-angle faults dip rather steeply away from the ranges, particularly those ranges having a core of quartz monzonite, and have their downthrown side towards the valleys. A second generalization is that a majority of the east-trending faults dip north, and a majority of the north-trending faults dip west. This is evident from inspection of the displacement symbols on the map (pl. 1). A cross section through Magruder Mountain shows a cumulative stratigraphic separation of at least 10,000 feet, downdropped on the north side. The three large faults north of the Palmettos involve several thousand feet more of dip-slip movement, the north side being downdropped in each case. Clayton Valley and Fish Lake Valley appear to be the two principal areas toward which dip-slip movement is directed, and they are interpreted as areas of subsidence.

Although the largest faults seem to have formed prior to or during the earliest of the Tertiary volcanic episodes, the Tertiary rocks themselves are cut by numerous faults of smaller magnitude. Radiometric ages of various Tertiary rocks affected by the faults indicate that much of the minor faulting is late Pliocene or younger. One of the most interesting patterns of faults affecting Tertiary volcanic rocks is that in the welded ash flows of the Grapevine Canyon area south of Gold Mountain (pl. 1). Here a series of three east-trending faults spaced 2 to 3 miles apart divide the welded ash flows into blocks elongated east-west. These blocks are in turn cut by a large number of curved northeast-trending faults that are convex toward the southeast and have their downthrown side consistently on the northwest. In this connection it may be mentioned that the same section of welded ash flows southeast of Gold Mountain, chiefly in Nye County, are cut by northeast-trending faults that have their downthrown side on the southeast. A line separating the two areas of opposite throw trends about S. 45° E. from the east end of Gold Mountain.

Low-angle faults or thrusts having dips less than 45° and mostly less than 20° are extremely common in the pre-Tertiary rocks of Esmeralda County, but they do not affect the Tertiary. These faults will be referred to as thrusts in this report. However, this usage carries no implication as to mode of origin of the faults (i.e., whether a result of compression or a result of gravitational gliding).

At least 50 percent of the contacts between pre-Tertiary rock units, excluding igneous rocks, are thrusts. In addition to the thrusts shown on the geologic map (pl. 1), there are many thrusts within formations such as the Emigrant and Palmetto that could not be shown because of the difficulty of mapping and limitations of scale. At least 75 percent of the thrusts have younger rocks in the upper plate, but some of the most extensive thrusts show older rocks on top of younger: The Wyman Formation, which is the oldest in the county, has not been seen in the upper plate of any thrust, but it forms the lower plate on a number of thrusts.

The thrusts are recognized mainly on the basis of stratigraphic evidence, supported in most but not all places by discordant structure. Where older rock units rest discordantly on younger — as for example, on Palmetto Peak west of Lida where the older Reed Dolomite rests on the younger Deep Spring and Harkless Formations — the thrust relationship is very easily recognized. Similarly, where a large stratigraphic gap exists — as east of hill 8390 on Mineral Ridge where the Harkless Formation rests on the Wyman Formation — the thrust relationship is readily recognized because a section of more than 5,000 feet is missing. Neither of these thrusts is marked by a prominent gouge or breccia zone, and bedding in the Wyman and Harkless Formations in the Mineral Ridge locality is roughly concordant. Where the upper part of the Emigrant Formation rests on platy siltstone of the Harkless Formation south of Palmetto Peak the exposed contacts seem nearly concordant in various outcrops and show no brecciation or other physical evidence of faulting. Yet knowledge that the lower part of the Emigrant Formation, as well as the entire Mule Spring Limestone, and at least part of the Harkless are missing is compelling evidence that the relationship between Harkless and Emigrant is that of a thrust.

Structural discordance, as well as stratigraphic evidence, is plainly visible along many thrusts. It is fairly common to see the Mule Spring Limestone dipping at angles up to 60° resting on gently dipping platy siltstone of the Harkless Formation, the contact between the two units being a nearly horizontal thrust with very little gouge or breccia. Apparently the platy siltstone afforded an easy surface for the limestone to slide on. Similarly, the shaly rocks of the Palmetto form the lower plate beneath the thin-bedded upper limestone unit of Emigrant Formation in several areas, as in the vicinity of Emigrant Pass and near the southern end of the Montezuma Range (pl. 1). Commonly the limestone in the upper plate of these thrusts is highly crumpled and tightly folded for several tens to several hundred feet above these thrusts.

It is not meant to imply from the foregoing that the less competent shale and siltstone units are invariably in the lower plate of the thrusts. The incompetent Palmetto Formation itself rests in thrust relation on older rocks in many parts of the county. Likewise the Harkless Formation forms the upper plate of thrusts in many places. In summary, almost every stratigraphic and lithologic combination — older rocks on younger, younger rocks on older, competent rocks on incompetent, and incompetent rocks on competent — may be seen in thrust relationship in the county. An unusual thrust exposed in the vicinity of Palmetto Wash near the California border shows quartz monzonite resting on the Reed Dolomite.

Along some thrusts involving carbonate rocks from thrust contacts the carbonate rocks for several tens of feet are intensely brecciated. The breccia is made up of angular fragments ranging from a fraction of an inch to several inches across in a matrix of very finely ground up carbonate. This type of material is most common in the pile of thrust sheets on the south flank of Mineral Ridge. Elsewhere in the county it is rather rare.

The only thrust that could be correlated with a fair degree of confidence from one range to another within the county is one exposed in the northern part of the Montezuma Range and in Clayton Ridge. This low-angle fault has Reed Dolomite, Deep Spring Formation, and Andrews Mountain Member of the Campito Formation in the lower plate in various localities, overridden by an upper plate (or in places multiple plates) of Poleta, Harkless, Mule Spring, and Emigrant Formations (pl. 1). Another thrust that has the Nopah Formation and Pogonip Group in the upper plate overriding shaly Mississippian rocks in the lower plate is exposed only in the extreme southern tip of Esmeralda County (pl. 1). However, this thrust is probably the Last Chance thrust recognized by Stewart and others (1966, p. D32) in the Last Chance Range and also in the Inyo Mountains at least 30 miles to the west, outside the county. A third thrust that may correlate over a large area is that having an upper plate of Emigrant Formation over various other units in the Palmetto Mountains, southern Montezuma Range, Clayton Ridge, Angel Island, Goldfield Hills, and Jackson Ridge.

Direction of transport on the thrusts is difficult to determine. Although thinly bedded rock units, like the Emigrant and Palmetto Formations, are commonly highly crumpled where they form the upper plate of thrusts, time did not permit the measurement of enough fold orientations to attempt determination of direction of transport. However, at four different localities northeast of Clayton Valley, folds were observed that are in close spatial relation and evidently clearly related in origin to well-exposed low-angle faults. At two of these localities, one east of the mouth of Paymaster Canyon and the other in General Thomas Hills, the fold axes strike N. 60° E. At a third locality, about 4 miles east-northeast of The Monocline, fold axes strike due east, and at a fourth locality, in the southern part of Paymaster Ridge, the strike of a fold axis is N. 25° E. Axial planes of the folds at all four localities dip northwest or north at low angles, and it appears that tectonic transport was towards the southeast. This is in general accord with the findings of Ferguson and Muller (1949, p. 9 and 12) for thrusts affecting the region of the Luning Embayment about 30 miles to northwest and with the findings of Stewart and others (1966) for a large thrust directly southwest of the county.

The question arises, however, whether the thrusts in the area north of Clayton Valley are features of regional scale or whether they are relatively local features formed by gravitational sliding off a structurally high area such as the Lone Mountain pluton. This type of sliding would probably have taken place under very shallow cover and perhaps the possibility of its occurring is slim. Nevertheless, it cannot be ruled out south and east of Lone Mountain inasmuch as all four of the axial planes related to thrusts dip at low angles toward the mountain. It would be reassuring to have similar data elsewhere in the county, preferably in the vicinity of other plutons, to support or deny the regional character of the thrusting. Such data might be obtained by measurement of the geometry of minor folds in areas where thinly bedded rocks are in close spatial relation to thrusts. A statistical consistency in the orientation of the axial planes of such folds would suggest the direction of tectonic transport. However, McKee (1962) measured the orientation of small folds in the Magruder Mountain-Palmetto Mountain area and found no strong preferred orientation.

The thrusts in the county are offset by, and are apparently older than, at least the great majority of high-angle faults. These thrusts probably formed largely in conjunction with the development of the oroflexural structures and with the intrusion of quartz monzonite plutons, which radiometric age dates suggest took place from Middle Jurassic onward into the early Tertiary.

All the layered pre-Tertiary rocks as well as some of the Tertiary rocks are tilted, and some are folded. The folds observed in pre-Tertiary rocks are almost entirely of the open type and from this and the prevalence of dips of 20° to 40° throughout almost the entire map area it appears that folding is rather uniformly gentle. Dips greater than 60° are rare except along the east side of the Lone Mountain pluton and locally elsewhere in the county. Tightly compressed beds were seen only in close proximity to thrust faults in such units as the thinly bedded limestone of the Emigrant Formation. These are small folds measuring only a few feet in amplitude. Tight drag folds are also present in the Wyman Formation on Mineral Ridge, northeast of Gold Mountain, east of Lone Mountain.

The trends of fold axes in pre-Tertiary rocks differ markedly, depending on location within the county. Generally the trends of both minor and major folds follow the trends of the Silver Peak-Palmetto-Montezuma oroflex and related oroflexes (pl. 1). Consequently, in most of the Silver Peak and White Mountains, trends of both major and minor folds are northwest. The trends swing around to east-west in the Palmettos, in Magruder Mountain, and in the vicinity of Mount Dunfee; and to northeast and north-northeast in the Montezuma Range, Clayton Ridge, southern Goldfield Hills, and Mount Jackson Ridge. On Mineral Ridge the trend of drag folds is dominantly northwest in the western part, but a prominent northerly trend prevails in the eastern part. In Weepah Hills, trends range from east-west in the southern part, to north-south in the eastern part, to northwest in the Lone Mountain area. A N. 60° E. trend prevails in Miller Mountain and the Volcanic Hills, and the trend is generally north in the Cedar Mountains. Thus from available data it appears that if the myriad of faults could be removed and the cover of Tertiary and Quaternary rocks stripped away, the county might appear from high in the air much like a giant tongue-shaped lava flow facing south, with open folds bending around in the Silver Peak-Palmetto-Montezuma oroflex and related concentric arcs in a manner comparable to the pressure ridges and intervening depressions in a lava flow.

The Tertiary rocks are unconformable on the pre-Tertiary and in general less intensely folded. However, dips of 20°–30° are common in Tertiary rocks, and locally in the western and northern parts of the Silver Peak Range, dips as high as 90° were observed. The tightest folds seen in Tertiary sedimentary rocks are west of Rhyolite Ridge (pl. 1) where a section about 1,500 feet thick is folded into a tight syncline whose axis seems to bend sharply in trend from north to east. An ash flow several hundred feet thick that underlies this sedimentary sequence is also involved in the folding. Tight folds of northwest trend were seen in the Tertiary sedimentary rocks on the southwest flank of the Monte Cristo Range (pl. 1). Several open folds trending northwest and having wave lengths of about 2 miles and opposed dips as high as 40° are present in Tertiary sedimentary beds in the southwest part of the Weepah Hills. From these observations it is clear that the Tertiary rocks, in some areas at least, are actually folded and not simply tilted.

A common relationship seen in many places is that of welded ash flow sheets dipping outward on the flanks of ranges at angles ranging from 10° to 60°. In several localities, as around the east end of Volcanic Hills, south and east of Gold Mountain, and east of Mount Dunfee, the dip of ash flows is opposed on opposite sides of the range. In other words, the ash flows appear to lie on these ranges as blankets, eroded away on the tops of the ranges, and the dips therefore cannot be readily explained by simple tilting. Possible interpretations are that the ranges have been arched up, or that much of the dip seen is initial dip resulting from emplacement of the ash flows on a rugged terrain. This latter interpretation is not in agreement with Ross and Smith (1961) who state that welded tuffs characteristically have very low initial dips.

STRUCTURE OF INDIVIDUAL RANGES

From the foregoing general description of structure it will be evident that the structure of individual ranges within the county differs markedly from one range to the next. For this reason a brief description of each range or mountain group is given below.

Silver Peak Mountains

The largest group of mountains within the county is known as the Silver Peak Mountains. They occupy an area of some 300 square miles and have roughly the shape of a parallelogram with an appendage projecting northward to Emigrant Peak (pl. 1). Two parallel belts of pre-Tertiary sedimentary rocks trending N. 50°–60° W. intruded by quartz monzonite plutons form the southwest and northeast parts of the mountains. Between these belts of older rocks is a thick pile of Tertiary sedimentary and volcanic rocks that occupy what must have been a topographic low in the early Tertiary terrain.

The belt that forms the northeastern part of the Silver Peak Mountains may be divided into two segments of approximately equal length. The southeast segment, known as Mineral Ridge, has a core of quartz monzonite that intrudes the Wyman Formation but nowhere reaches the Reed Dolomite. Broadly, the structure of Mineral Ridge, as defined by the Wyman Formation, is that of a gentle open anticline plunging at an angle of 10°–15° S. 55° E. Superimposed on this broad structure are several clearly defined secondary folds having amplitudes of several hundred feet and trending parallel to the ridge. The best exposed of these is a syncline with Reed Dolomite in the trough just north of the Mary mine (pl. 2). In addition to these large secondary folds, the Wyman Formation in Mineral Ridge contains abundant drag folds ranging from less than an inch to about 20 feet in amplitude. Most of these folds are overturned or recumbent with axes subparallel to the main ridge and axial planes dipping southwest. However, towards the eastern end of Mineral Ridge, these small folds are diversely oriented, some being at right angles to the ridge.

Outliers of Reed Dolomite overlie the Wyman Formation in many places on Mineral Ridge. Most of these outliers seem to be structurally concordant on the Wyman, but a few seem to be in slight discordance on small low-angle faults. The remaining pre-Tertiary formations rest in thrust relationship mainly on the Wyman but locally on the Reed. On the central part of the ridge is a large klippen of Deep Spring Formation on a very low-angle thrust over Wyman, Reed, and quartz monzonite (pl. 1). The highest part of the ridge (8,390 ft.) is occupied by partial sections of a number of formations including Deep Spring, Campito, Poleta, and Harkless. Along the east side of this 8,390-foot peak, the Harkless rests on Wyman, and on the west side, the Deep Spring is on Wyman. The top of the peak is Campito, and it appears that at least three thrusts are necessary to account for the observed relationships (pl. 1).

Low on the south side of Mineral Ridge, about 2 miles east of Red Mountain (pl. 1), partial sections of all units ranging from Deep Spring to Emigrant are piled up on a set of at least five imbricate thrusts (pl. 1). These thrusts seem to dip southward at an angle of approximately 20°, about parallel to the southwestern slope of Mineral Ridge.

A high-angle normal fault having an observed dip of 60° NE. extends for at least 8 miles along the northeastern slope of Mineral Ridge and separates the Wyman and Reed Formations on the footwall from various units of the Lower Cambrian on the hanging wall. These Lower Cambrian units strike generally north-northwest at an angle to the trend of the Ridge and are cut and repeated by a series of concealed northward-trending high-angle faults, most of which are downdropped on the west side. At least a dozen high-angle faults also of northward trend and downdropped on the west side cut nearly across the eastern part of Mineral Ridge. Many of these faults contain quartz veins that locally yielded heavy metals.

The northwest segment of Mineral Ridge is entirely different structurally from the southeast part and is separated from it in the vicinity of Black Canyon (pl. 1) by a thrust involving the Harkless and other Lower Cambrian formations in the upper plate. From Black Canyon northward, units ranging from Reed Dolomite up through the Ordovician Palmetto Formation are stacked in a series of thrust plates, some in normal order and some in reverse, and covered here and there by Tertiary rocks. The amount of Tertiary cover increases toward the northwest. The most conspicuous thrust in this segment brings the Middle and Upper Cambrian Emigrant Formation over the Ordovician Palmetto Formation. This thrust is well exposed in the vicinity of Emigrant Pass (pl. 1).

Also cutting the Paleozoic formations north of Black Canyon are three arcuate high-angle faults, convex southward and downdropped on the north side. These faults postdate the thrusts described above. The general trend of bedding as far north as Emigrant Pass is north-northeast. From there northward the strikes change to northwest and to nearly west on the slopes west of Emigrant Peak.

The belt of rocks that forms the southwest part of the Silver Peak Mountains from Oasis Divide northwestward to the vicinity of Dyer is an extension of the eastward-trending Palmetto Mountains (pl. 1). The core of this belt is quartz monzonite of the Palmetto pluton. The pluton is flanked on either side and at its northwest end by Lower Cambrian and Ordovician rocks that strike generally northwest, parallel to the ridge as far as McAfee Canyon. Dips are mostly north on both sides of the pluton. McAfee Canyon is the site of a large high-angle fault downdropped on the north side. North of McAfee Canyon, strikes in the Harkless and Palmetto Formations are generally north but locally variable. A thrust in the area north of McAfee Canyon has Harkless in the upper plate over Ordovician. South of the high-angle fault in McAfee Canyon the same thrust extends eastward for about a mile to the extreme west end of the Palmetto pluton. Another thrust has Harkless Formation in the upper plate over Poleta Formation. South of the main pluton and a narrow section of sedimentary rocks is a second pluton (Palmetto Wash pluton) probably connected at shallow depth to the Palmetto pluton. This pluton is locally cut by numerous diorite dikes that strike northwest and dip north.

Between the two belts of pre-Tertiary rocks that form the northeast and southwest parts of the Silver Peak Mountains is the topographically higher central area made up largely of Tertiary sedimentary and volcanic rocks. The oldest Tertiary rocks in this part of the range are conglomerates exposed in a large area east of Red Mountain, where the north-northeast strike is nearly at right angles to Mineral Ridge and dips are at angles as high as 70°. This relationship would seem to suggest a fault between the conglomerate and the pre-Tertiary rocks to the north but since none was observed, the conglomerate may be a fluvial channel-fill deposit. Overlying the conglomerate unconformably east of Red Mountain are shaly rocks that also strike generally north but which are folded into a series of folds trending northeast. The same two Tertiary sedimentary units crop out on the west side of the Silver Peak Mountains, where the conglomerate lies unconformably on pre-Tertiary rocks that crop out low down in the foothills. The shaly rocks here do not lie directly on the conglomerate but on a unit of andesitic volcanic breccia that intervenes. Strikes in these older Tertiary rocks are generally north and northwest, and dips are dominantly east and north.

The next higher Tertiary units are the vent tuffs of Rhyolite Ridge and the overlying sedimentary beds that are involved in the synclinal fold mentioned earlier. These units, which are probably of early Pliocene Age, have apparently undergone about the same degree of deformation as the older shaly and tuffaceous unit. On the other hand, the porphyritic latite, basalt, and sedimentary rocks that form the highest part of the Silver Peak Mountains are unconformable on the folded rocks, here eastward-dipping, and therefore have undergone less deformation. The porphyritic latite of this younger untilted sequence has a radiometric age of about 5.9 million years, and from this it appears that the Silver Peak Mountains were tilted eastward sometime during early to middle Pliocene time. Eastward tilting may also have occurred earlier, but the evidence is not clear.

The entire sequence of Tertiary rocks in the central part of the Silver Peak Mountains is cut by a series of northeast-trending faults. Most of these faults dip west, have a slightly arcuate trend, convex toward the southeast, and are downdropped on the northwest side. A few are downdropped on the southeast side. The silver-bearing veins of the Red Mountain mining district occur along this set of northeast-trending faults.

Palmetto Mountains

For purposes of this report, the Palmetto Mountains are defined as extending from Oasis Divide eastward and northeastward to the low divide through which passes the road from Lida via Mount Jackson to Silver Peak. This divide is sometimes referred to as "Railroad Pass" by local residents. The Palmettos are the eastward continuation of the southern part of the Silver Peak Mountains and make up an eastward-trending segment of the Silver Peak-Palmetto-Montezuma oroflex. They are formed largely by the eastern end of the Palmetto pluton and the intruded rocks that partly surround it. A mass of porphyritic latite makes up part of the eastern end of the Palmettos, and a belt of volcanic breccia on the north flank of the main ridge also forms a topographically rugged part of the mountains. Palmetto Peak in the extreme southern part of the Palmetto Mountains is composed of Precambrian and Paleozoic rocks.

The outcrop of the Palmetto pluton widens eastward from a constriction at Oasis Divide and comes to a blunt eastern end north of peak 9250. Not shown on the map is a small body of quartz monzonite similar to the Palmetto pluton and covering only a few acres which crops out 8 miles farther east near the extreme eastern end of the mountains. The rocks intruded by the Palmetto pluton are largely the Ordovician Palmetto Formation; locally the pluton shows intrusive relations to the Harkless and Emigrant Formations. South of the pluton the Ordovician rocks are highly silicified and hornfelsed, and intruded by numerous dikes of rhyolitic rock that dip north; strikes of bedding are east-west, approximately parallel to the pluton, and dips are south. At the northeastern end of the pluton bedding tends to wrap around the pluton and dips are mainly away from it, but farther northeast towards "Railroad Pass" strikes are northeast and dips consistently southeast in a section of Lower Cambrian rocks. Rhyolite or quartz latite dikes that also strike northeast and dip northwest, intrude these

Cambrian rocks. One large mass of rhyolitic rock that locally has a granitoid texture strikes at right angles to the range just southwest of "Railroad Pass." From the abundance of rhyolitic dikes in the eastern Palmettos and the presence of at least two very small bodies of quartz monzonite, it is inferred that the Palmetto pluton continues at shallow depth beneath the eastern Palmettos and probably northeastward beneath the southern part of the Montezuma Range as well.

A large high-angle arcuate fault downdropped on the north side forms the approximate northern boundary of the pluton for much of its outcrop length in the Palmettos. On the hanging wall side are sporadic occurrences of Cambrian and Ordovician rocks that dip north or south, and Tertiary volcanic rocks that dip mainly south towards the pluton. These Tertiary rocks overlie southward-dipping Cambrian and Ordovician rocks that crop out in several ridges along the south side of Clayton Valley.

In addition to the large high-angle fault along the north side of the Palmetto pluton, the rocks are cut by numerous other high-angle faults, most of which strike roughly parallel to the range but some of which strike transversely to it. Most of those paralleling the range are downdropped on the north side and those transverse to it are downdropped on the west side.

One of the most prominent thrusts in the Palmettos is in the extreme southeastern part, on Palmetto Peak, where the Cambrian Emigrant Formation in part overlies the Ordovician Palmetto Formation on a low-angle thrust surface. One synclinal fold trending N. 25° E. was mapped in the Emigrant of the upper plate. Both the Emigrant and Palmetto Formations are cut by numerous rhyolitic dikes that strike mostly northeast and dip northwest.

Palmetto Peak, or Palmetto Mountain as it is sometimes called, is an area of complex thrusting. At least four thrusts are exposed, two east and north of the peak and two west and south. The highest point (pl. 1) is Harkless Formation, which to the east is overridden by a block consisting of northward-dipping Reed Dolomite and Deep Spring Formation. This plate also rests in part on northward-dipping strata of the Deep Spring Formation and the Andrews Mountain Member of the Campito Formation which, together with the Montenegro Member of the Campito Formation and the Poleta Formation, form a lower thrust plate that also overrides Harkless Formation. West and south of the peak the Harkless, which dips mainly south, is overridden by southward-dipping Emigrant Formation, and farther west a higher plate of south-dipping Palmetto Formation rests in some places on the Emigrant and in other places on the Harkless. Thus it appears that the Harkless Formation in the Palmetto Peak area forms the lower plate of four thrusts. The relationship between the thrusts east of the peak and those west of it is not definitely known, but it seems likely that the plates to the east containing Reed, Deep Spring, and Campito Formations are structurally higher than those to the west. The lower of the two eastern thrusts is inferred to continue south across Lida Valley into Magruder Mountain.

Magruder Mountain

Magruder Mountain lies directly south of the Palmetto Mountains, being separated from them only by the narrow topographic lineament marked by Palmetto Wash and Lida Valley. The mountain occupies the same relative position in the Silver Peak-Palmetto-Montezuma oroflex as the Palmettos, but, as pointed out by McKee (1962, p. 94), who is responsible for mapping much of the Magruder Mountain and Palmetto Mountains area, the structure of the two neighboring mountain masses is highly contrasting. The Palmettos are more complex in that they consist of a mosaic of high-angle and low-angle faults, whereas Magruder Mountain is essentially a southeastward-dipping homocline composed of Precambrian and Cambrian rocks cut by two groups of high-angle faults. One group strikes northeast and another group strikes northwest. Those that strike northeast have greater dip separation, are arcuate in plan, being convex toward the southeast, and dip northwest. A section drawn across Magruder Mountain indicates a net cumulative stratigraphic separation of over 10,000 feet on about a dozen high-angle faults, the north side being downdropped. Most of this separation is accounted for by northeastward-trending faults.

A fault of major importance that is common to both Magruder Mountain and Palmetto Peak is a thrust, previously described, which is exposed east of Palmetto Peak. This thrust, here called the Magruder thrust, brings the Reed, Deep Spring, and Campito Formations over the Lower Cambrian Poleta and Harkless. According to McKee (1962, p. 92), this fault has an eastward dip of about 25° on the east side of the mountain. Toward the south it bends westward around the mountain and steepens in dip to about 70°. In the area east of Palmetto Peak the dip has not been measured, but judging from the topographic expression of the fault its dip appears to be about 15° toward the northeast. As previously mentioned, the Cambrian rocks in Magruder Mountain, and the Cambrian and Ordovician rocks in the lower plates west of Palmetto Peak, dip southward in homoclinal fashion. In contrast, the Reed, Deep Spring, and Campito Formations in the upper plate of the Magruder thrust form an approximately symmetrical anticline, the axis of which trends N. 65° E., located approximately in Lida Valley. This anticline has no counterpart in lower plate rocks either to the northeast or to the southwest.

Montezuma Range

The Palmetto Mountains became two well-defined ranges, called Clayton Ridge and the Montezuma Range, northeast of "Railroad Pass." These and probably the Goldfield Hills and Mount Jackson Ridge form the eastern limbs of the southward-facing Silver Peak-Palmetto- Montezuma oroflex (pl. 1). Of these four topographic elements the Montezuma Range is by far the most prominent. It extends for about 20 miles in a N. 30° E. direction but is cut midway by a transverse valley. Its highest point is Montezuma Peak with an altitude of 8,376 feet.

For the first 5 miles northeast of "Railroad Pass," the structure of the range is comparatively simple. An upper plate of southeastward-dipping Emigrant Formation is thrust over a homoclinal sequence of southeastward-dipping Cambrian rocks about a mile north of the pass. The Cambrian rocks are cut by numerous rhyolite dikes that strike northeast parallel to bedding and dip northwest, and by two small bodies of quartz monzonite. Several northeastward-trending high-angle faults, downdropped on the west side, cut the Emigrant Formation in the upper plate, and a few cut the rocks of the lower plate.

About 5 miles northeast of "Railroad Pass" is the southern edge of a large mass of rhyolitic tuff overlain in places by agglutinate. The volcanic mass extends northward to beyond Montezuma Peak, and westward to Clayton Valley (pl. 1). Dips throughout much of this mass are on the order of 5° in various directions, but locally, as on Montezuma Peak they range as high as 20° westward. The large mass of vent tuff and the presence of much agglutinate north and east of Montezuma Peak indicates that a large rhyolite volcano was probably located in the area just east of Montezuma Peak.

Beneath the tuff on the west side of Montezuma Peak is a belt of Harkless Formation that rests in thrust relationship on the Reed and Deep Spring Formations. The rocks in the lower plate of this thrust dip consistently west at low angles whereas dips in the Harkless of the upper plate are more variable but mainly south and west. A number of northward-trending high-angle faults, downdropped on the east side, cut both the upper and lower plate rocks.

About 2 miles north of Montezuma Peak another thrust brings Poleta and Harkless Formations over Andrews Mountain Member of the Campito Formation. A higher thrust is indicated by the presence of a klippe of Poleta resting on the Harkless. The strike of bedding is consistently north-northeast and dips are west at moderate angles in all three plates of this area.

Near the north end of the range (near secs. 13, 14, and 15, T. 2 S., R. 41 E.) a belt of air-fall tuff and dark rhyolite or dacite that lies transverse to the range may obscure an important fault zone. The reason for this inference is that directly north of this belt of volcanic rock a small monzonite pluton trends northwest and intrudes Paleozoic rocks that strike dominantly west-northwest in marked contrast to the north-northeast strikes south of the belt of volcanic rocks.

Just off the northwest end of the Montezuma Range is a northeastward-trending ridge about 3 miles long composed of gently folded Harkless Formation intruded by westward-dipping rhyolite and diorite dikes and small bodies of quartz monzonite. The structural relation of this block to the northern end of the Montezuma Range is not clear. The presence of several small plutons and numerous dikes suggests that the entire north end of the Montezuma Range is underlain by plutonic rock at shallow depth.

Clayton Ridge

Clayton Ridge, like the Montezuma Range, is one of the eastern limbs of the Silver Peak-Palmetto-Montezuma oroflex. Structurally it is highly variable from its southern end north of the "Railroad Pass" road from Lida to Silver Peak to its northern end at the low pass occupied by the road from Goldfield to Silver Peak. It is inferred that Clayton Ridge is separated from Clayton Valley by a high-angle fault, which is mapped in places, having movement that both predates and postdates the Tertiary volcanic and sedimentary rocks in the central part of the ridge.

The south end of Clayton Ridge is composed principally of the Palmetto Formation dipping gently east and southeast. Farther north the Campito, Mule Spring, and Emigrant Formations make their appearance. They and the Palmetto are separated from each other by northeastward-trending high-angle faults, but together they form a thrust plate that overlies the Andrews Mountain Member of the Campito Formation. Bedding in both the upper and lower plates dips east, and locally the angle of dip is vertical. About 5 miles from the southern end of the ridge, along the eastern side of Clayton Valley, the Andrews Mountain Member is intruded by small bodies of quartz monzonite.

The same mass of rhyolitic vent tuff that occurs in the Montezuma Range crops out over a distance of about 5 miles in the central part of Clayton Ridge. As in the Montezuma Range, this volcanic rock dips at very low angles and is cut by two sets of high-angle fractures — one striking north-northeast and the other about east. Displacement on these fractures seems to be small although some fractures are traceable for 3 or 4 miles.

North of the mass of Tertiary rhyolitic tuff are two blocks of highly faulted Precambrian and Cambrian rocks each of which is separable into two principal thrust plates. The lower plate in the southern of the two blocks consists of Reed and Deep Spring Formations and of the Andrews Mountain Member of the Campito Formation exposed along Clayton Valley and dipping gently east, overlain by an upper plate of Poleta, Harkless, Mule Spring, and Emigrant. The thrust has been displaced along much of the outcrop by a high-angle fault that drops the upper plate Harkless and Mule Spring on the east down against the lower plate Campito Formation on the west. The upper plate rocks dip in various directions and contain at least two additional thrusts, one defined by numerous klippen of structurally discordant Mule Spring over Harkless and a higher plate having Emigrant over Mule Spring.

A window of Andrews Mountain Member of the lower plate forms a topographically low area transverse to Clayton Ridge and separates the northern of the two blocks of Precambrian and Cambrian rocks from the southern. A small body of light-colored quartz monzonite cuts into upper plate rocks just north of this window (pl. 1). In the northern block the lower plate is exposed along the eastern side of the ridge and is made up entirely of Andrews Mountain Member dipping west. The upper plate rocks are Poleta and Harkless Formations that also strike generally north and dip west. These rocks are cut by three northward-trending high-angle faults each downdropped on the east side.

The lower thrust in the northern part of Clayton Ridge is tentatively correlated with the thrust that brings Harkless, Mule Spring, and Emigrant Formations over the Andrews Mountain Member in the southern part of the ridge, and also with the Montezuma thrust.

Paymaster Ridge

This ridge is a northward continuation of Clayton Ridge from both a topographic and structural standpoint. The narrow divide at which the boundary between the two ridges is arbitrarily drawn contains no transverse structure of importance, and formation contacts as well as three northward-trending high-angle faults project across the divide with little or no apparent offset.

The southern part of the ridge contains several thrust sheets, the highest carrying siltstone of the Harkless Formation over the Poleta Formation. The Harkless in the upper plate of this thrust is folded into broad open folds trending N. 35°–50° E. Other thrusts in the southern part of Paymaster Ridge show Poleta over the Montenegro and Andrews Mountain Members of the Campito Formation.

East of the mouth of Paymaster Canyon are two large eastward-trending faults spaced a little over half a mile apart (pl. 1). The southern of the two faults dips vertically in some places and is generally steep whereas the northern fault dips 25° N. On both faults the north side is depressed relative to the south. The strike of bedding in the Harkless Formation between the two faults, and for about a mile in the hanging wall of the northern fault, are east-northeast in contrast to the prevailing north-northeast trends elsewhere in the ridge.

The northern part of Paymaster Ridge is chiefly green siltstone of the Harkless Formation overridden by a thrust plate composed of the Mule Spring, Emigrant, and Palmetto Formations.

Goldfield Hills and Mount Jackson Ridge

These two low ranges appear to be eastern limbs of the Silver Peak-Palmetto-Montezuma oroflex. They are separated from the Palmetto Mountains and Montezuma Range by a valley in which one or more large northward-trending faults are inferred. The western end of Mount Jackson Ridge is mostly low-dipping Tertiary tuffaceous and sedimentary rock intruded by rhyolite domes and covered by rhyolite and andesite flows (pl. 1).

The central part of the Goldfield Hills is composed mainly of Harkless, Mule Spring, and Emigrant Formations and a small area of Palmetto Formation. The dominant trend of bedding is about N. 30° E., but near a thrust fault that trends transverse to the range, the beds strike about east. The thrust brings a plate of Emigrant Formation over Harkless and Mule Spring Formations. At least one other klippe of this plate crops out in the vicinity of hill 6431 north of the main exposure of the thrust (pl. 1). A number of northeastward-trending high-angle faults cut upper and lower plate rocks.

The northern part of Goldfield Hills consists predominantly of Tertiary volcanic and sedimentary rocks except for a few inliers of altered Palmetto Formation and quartz monzonite in the Goldfield mining district. The Tertiary rocks in the Goldfield district show a concentric outcrop pattern, and the district is believed to be related to a volcanic center from whence the nearby volcanic material was derived. The district is also on or very close to the northwestward-trending Walker Lane of Locke and others (1940).

The central and northern part of Mount Jackson Ridge is made up principally of the Harkless, Mule Spring, and Emigrant Formations and is very similar in its structural makeup to the central part of Goldfield Hills. A thrust believed to be correlative with the one in Goldfield Hills brings a plate of Emigrant Formation over the Harkless and Mule Spring. The dominant trend of bedding is north-northeast, and numerous high-angle faults cut the rocks of both the upper and lower plates.

Slate Ridge

This range occupies the area between Magruder Mountain and Oriental Wash (pl. 1). It diverges from Magruder Mountain and has an easterly trend and arcuate form similar to the Palmetto Mountains. The range is more or less concentric with the Silver Peak-Palmetto-Montezuma oroflex and is evidently part of the same gross structure.

Approximately the western half of Slate Ridge is quartz monzonite of the Sylvania pluton. A few scattered pendants of Wyman Formation are contained in it. These pendants are oriented generally west-northwest parallel to the range, and bedding trends are similarly about parallel to the range in most of the inclusions.

From the vicinity of Gold Point eastward, Slate Ridge is composed in large part of Precambrian and Cambrian rocks into which the eastern end of the Sylvania pluton projects in fingerlike fashion. The extreme eastern end of Slate Ridge is welded and nonwelded rhyolitic ash-flow material that covers the older rocks unconformably. Southwest of Gold Point the quartz monzonite intrudes Wyman Formation that strikes generally north, dips east, and south, southeast, and near Gold Point is overlain in places by Reed Dolomite. This section is repeated in Mount Dunfee about a mile to the east across an alluviated valley. Here a complete section of the Reed and Deep Spring Formations is exposed, as well as about 2,000 feet of the Wyman Formation and a thick section of Campito Formation, including both the Andrews Mountain and Montenegro Members. The structure of Mount Dunfee is that of an anticline plunging nearly due east at a moderate angle and disrupted by high-angle faults.

An inferred high-angle fault obscured by alluvium forms the northern boundary of Slate Ridge as far east as Mount Dunfee, and from there eastward the fault is exposed, forming the boundary between the above-described Precambrian and Cambrian rocks on the south side and downdropped Cambrian rocks on the north side. The stratigraphic offset on this fault is at least 4,000 feet. Two other easterly trending faults were traced the entire length of Slate Ridge. Where these faults are in the Sylvania pluton they are recognized chiefly as a soft alteration zone that in places is as much as 1,000 feet wide. At one place in the pluton they apparently merge and then split again. Both faults are downdropped on the north side and their main movement seems to have both preceded and followed the deposition of Tertiary ash flows.

Along the south side of Slate Ridge in the upper reaches of Oriental Wash are large outcrop areas of Wyman Formation that strike east-northeast and dip mainly south. Several areas of Reed Dolomite rest in structural discordance on the Wyman here, but these are minor thrusts, and no large thrusts are recognized in the Slate Ridge area.

Ash flows that crop out near the eastern end of Slate Ridge dip mostly at low angles away from the older rocks that form the core of the ridge, suggesting that the ridge has been arched up vertically since the ash flows were deposited. An elongate area of ash-flow material directly southeast of Mount Dunfee is essentially synclinal.

Gold Mountain Area

Gold Mountain is structurally similar to the western half of Slate Ridge. It is made up chiefly of quartz monzonite that appears to be continuous under Oriental Wash with the Sylvania pluton (pl. 1). The pluton projects eastward as fingerlike bodies into the intruded Wyman Formation, which dips mainly south. Locally the Wyman is folded into tight drag folds that plunge chiefly southwest.

Between Gold Mountain and Grapevine Canyon is a large area of welded ash flows belonging to the Timber Mountain Tuff. These ash flows strike east-northeast, dip southeast, and are cut by three prominent east-trending faults downdropped on the north and minor northeast-trending faults downdropped on the northwest. These latter faults seem to branch off the east-trending ones. The same section of welded ash flows east of Gold Mountain strikes northeast, dips northwest, and is cut by northeast-trending faults that are downdropped on the southeast, the reverse relationship from that in the area south of Gold Mountain.

Grapevine Mountains

The extreme northern end of the Grapevine Mountains extends into the southern tip of Esmeralda County. The pre-Tertiary rocks of this range include the Nopah Formation and Pogonip Group of Cambrian and Ordovician Age and a sequence of shaly rocks of Mississippian Age. The Nopah and Pogonip strike northwest, dip northeast, and rest in low-angle thrust relationship on the Mississippian rocks. This appears to be part of a major thrust that has also been mapped by Stewart and others (1966) in the Last Chance Range at least 20 miles northwest of the Grapevine Mountains.

Tertiary rocks, including welded ash flows (Timber Mountain Tuff) and dacite, overlie the Paleozoic rocks unconformably. They lie in homoclinal sequence and strike mainly northeast and dip northwest.

Monte Cristo Range and Cedar Mountains

The Monte Cristo Range and Cedar Mountains together form a topographic arc convex southward and approximately concentric with the Silver Peak-Palmetto-Montezuma oroflex. However, as most of the Monte Cristo Range is made up of Tertiary rocks, with only scattered outcrops of Paleozoic and Mesozoic rocks, the case for a structural arc or oroflex in the pre-Tertiary rocks is not convincing. Bedding attitudes in scattered pre-Tertiary rocks in the southwestern part of the Monte Cristo Range spread from about north to N. 60° W., and in the Cedar Mountains the strike of bedding averages a little west of north. In the southern part of the Monte Cristo Range the few inliers of mainly Ordovician rocks show contorted bedding and varied attitudes, so that a general strike could not be determined.

One of the largest thrusts in Esmeralda County crops out in the southwestern part of the Monte Cristo Range as well as in the Candelaria Hills to the northwest. This thrust, which brings Ordovician rocks over Triassic in some places and Permian rocks over Ordovician in others, was named the Monte Cristo thrust (Ferguson and Muller, 1949, p. 48–49; Ferguson and others, 1953). The thrust appears to dip west, and drag folds in the Ordovician rocks indicate that the upper plate moved east or southeast.

Miller Mountain

This area like the Candelaria Hills lies only partly in Esmeralda County. A sequence of Lower Cambrian rocks of somewhat different lithology than the Lower Cambrian exposed elsewhere in the county forms the southern part of Miller Mountain. These rocks are folded along axes trending N. 60°–70° E. and dips are mostly in the range of 30°–55°. The most prominent fold is an anticline (shown on pl. 1) called the Black Mountain anticline by Wilson (1961).

The sequence of Cambrian rocks is intruded by a small body of quartz monzonite and overlain unconformably on the north by welded ash flows. About 3 miles farther northeast toward the Candelaria Hills is a large inlier of Ordovician rocks that strike nearly east and dip north at moderately high angles.

Candelaria Hills

The main part of Candelaria Hills is in Mineral County, and only the eastern end of this eastward-elongate topographic feature extends into Esmeralda County. The rocks are dominantly the Ordovician Palmetto Formation, the Permian Diablo Formation, and the Triassic Candelaria Formation (pl. 1). Strikes are dominantly east, and dips are north at moderate to high angles. The Monte Cristo thrust mapped by Ferguson and others (1953) is an important structural feature in the extreme eastern end of the hills.

Volcanic Hills

These hills, situated between Miller Mountain and the north end of Fish Lake Valley, are composed mainly of volcanic rocks but contain an area of 1 to 2 square miles of Lower Paleozoic rocks near their eastern end (pl. 1). The exposed formations include the Harkless, Mule Spring, Emigrant, and Palmetto. As in Miller Mountain, the formations are folded along major axes trending northeast; the Harkless Formation contains small drag folds whose axes plunge southeast and also a locally prominent cleavage that strikes northwest. The Palmetto Formation rests in thrust relationship on the Cambrian rocks.

Tertiary rock units strike mainly east in the western part of the Volcanic Hills but nearly north in the eastern part. Maximum observed dips were 18°, and over much of the area, dips are 5° or less.

White Mountains

A small part of the White Mountains, including the northern end, is within the boundaries of Esmeralda County. About two-thirds of the rock in this block is quartz monzonite of the Inyo batholith. This rock is largely devoid of prominent planar or linear structures. The remaining third of the rock consists of inclusions and pendants of highly metamorphosed rocks including the Wyman, Reed, Palmetto, and probably Harkless Formations. Bedding trends in the Palmetto Formation, the outcrop of which is restricted to the extreme northeast flank of the batholith north of Middle Creek (pl. 1), range from west to north but are mostly west-northwest. Bedding strikes in the Wyman, Reed, and Harkless(?) Formations, which crop out south of Chiatovich Creek, range from east to east-northeast. Dips are north in some places and south in others, and it appears likely that the rocks in these pendants and inclusions are rather closely folded.

From Mustang Mountain eastward (pl. 1), the rocks are Tertiary volcanic and sedimentary rocks that dip generally at very low angles and are in part contiguous with Tertiary units in the Volcanic Hills to the east.

Davis Mountain is capped by a large area of basalt that dips gently east, indicating that the range is tilted eastward. From various lines of structural and geomorphic evidence Fiedler (1937, p. 34) also concluded that the White Mountain block is a horst tilted eastward.

An impressive feature in the White Mountain area is the series of fault scarps in Holocene alluvium along the eastern front of the range and also the local groups of scarps in Fish Lake Valley several miles east of the front in the vicinity of Indian Creek (pl. 1). The scarps along the mountain front strike N. 15° to 30° W., face east, and show the east side downdropped. Scarps near Perry Aiken Creek have a combined indicated dip slip of about 250 feet where they displace older alluvium. The strike of faults north and south of Indian Creek (pl. 1) ranges from north to N. 35° E. About half of these scarps face west, and the remainder face east. Displacement ranges from a few feet to possibly 20 feet. One fault about a mile west of Dyer (pl. 1) strikes N. 60° E. and shows the south side downdropped.

Bryson (1937, p. 47), after studying the fault scarps in alluvium at the mouth of Perry Aiken Creek in detail, concluded from their irregular pattern that the movement on the main fault separating the White Mountain block from Fish Lake Valley was essentially vertical. However, the distribution of various pre-Tertiary rock units on either side of Fish Lake Valley indicates a probable right-lateral separation of at least 18 miles. Farther southeast along the continuation of this fault, Stewart (1967), from several lines of stratigraphic evidence, has concluded that the right-lateral separation is at least 50 miles.

Hills South of Tonopah

The hills south of the town of Tonopah (Nye County) are principally Tertiary volcanic rocks with subordinate Tertiary sedimentary rocks, and include one area of pre-Tertiary rocks about 10 miles south of Tonopah. The Tertiary rocks are in most places nearly horizontal or display only very low dips. But locally, adjacent to rhyolite and quartz latite plugs and domes, the beds are inclined to near vertical by the force of intrusion. The Tertiary rocks are cut locally by numerous faults but nowhere within Esmeralda County is faulting prominent. The main trends of observed faults are northwest and nearly west.

The pre-Tertiary rocks crop out in a mining district known as the Southern Klondyke district. They include the Harkless, Mule Spring, and Emigrant Formations which strike northeast, dip southeast at moderate angles, and are overridden by a thrust plate of Palmetto Formation (pl. 1). Two very small bodies of muscovite-rich quartz monzonite intrude the Mule Spring and Emigrant Formations discordantly.

Weepah Hills

The low mountains at the north end of Clayton Valley and along the west side of Paymaster Canyon are made up of Precambrian, Cambrian, and Ordovician rocks intruded by a few rhyolite dikes that crop out prominently (pl. 1). A mass of quartz monzonite (Weepah pluton) intrudes these rocks in the northern part of Weepah Hills. In the western part of the Weepah Hills, Tertiary sedimentary rocks and subordinate volcanic rocks unconformably overlie the older formations.

The formations in the extreme southern part of Weepah Hills strike generally east and are locally folded into open folds trending east. Near Paymaster Canyon the strike of formations and fold axes swings northeast and finally north, thus defining a nearly right-angled bend, the axis of which trends about N. 45° W. The formations dip generally east in homoclinal sequence for 4 to 5 miles up the west side of Paymaster Canyon where they are overridden by a thrust plate of the Palmetto Formation. The same thrust probably crops out about 4 miles northeast of The Monocline where at least two other thrusts are also present (pl. 1). The indicated direction of transport of the thrust, with Emigrant Formation over Mule Spring Limestone, is from north to south as shown by tight eastward-trending folds overturned south in thin-bedded limestone of the upper plate. An extensive thrust in the central and northern parts of the Weepah Hills has mainly Campito Formation in the upper plate overriding chiefly Reed Dolomite and Mule Spring Limestone. Direction of tectonic transport on the upper plate of this thrust could not be determined.

In the extreme northern part of Weepah Hills in the area between the Weepah and Lone Mountain plutons, strikes of bedding and fold axes range from north to northwest and east. Dips are locally steep and overturned, and some of the shaly rocks have a weakly developed schistosity.

Tertiary sedimentary rocks in the western part of Weepah Hills are folded into a series of gentle folds that trend mostly N. 60°–70° W. This is the same general trend as folds in the Esmeralda Formation between the Silver Peak and Monte Cristo Ranges southeast of Columbus Marsh.

General Thomas Hills and Lone Mountain

The General Thomas Hills lie adjacent to the southeast end of the Lone Mountain pluton. They have much in common with the extreme northeastern part of the Weepah Hills from which they are separated only by the northern end of Paymaster Canyon (pl. 1). In the northern part of General Thomas Hills the Poleta and Harkless Formations change in strike from nearly east to about north as they wrap around the southeast end of the quartz monzonite pluton. However, a belt of diorite about half a mile wide, trending about east, intervenes between the Cambrian rocks and the pluton in the extreme northern part of the hills. About a mile south of the diorite a thrust sheet of metamorphosed Mule Spring Limestone overrides the Harkless, and still farther south are two higher thrust plates — one of Emigrant Formation overriding the Mule Spring, and a second and higher one consisting of Palmetto Formation overriding the Emigrant and Mule Spring Formations.

North of the eastward elongate body of diorite (pl. 1), the Poleta and Harkless Formations crop out as a belt striking north and dipping east along the east side of the Lone Mountain pluton. About 5 miles north of the diorite the Wyman, Reed, and Deep Spring Formations crop out in sequence on the northeast flank of the pluton and are overridden by a thrust plate that is probably Harkless Formation. Dips are mostly northeast away from the pluton, but locally they are steep to the southwest and apparently overturned. Drag folds a few feet across and plunging steeply southeast are present locally in the Wyman Formation. A swarm of rhyolite dikes, trending mostly northwest more or less parallel to bedding, cut the metamorphosed Precambrian and Cambrian sedimentary rocks.

On the west side of Lone Mountain the Wyman and Reed Formations dip consistently southwest away from the pluton. A series of faults striking N. 50°–60° E. and dipping steeply northwest bound the northern side of the pluton. This fault zone is part, perhaps a branch, of a major fault zone believed to occupy Big Smoky Valley. One manifestation of the fault zone along the north side of Lone Mountain is a series of fault scarps in Holocene alluvium along the south side of the valley (pl. 1). These scarps, traceable over a distance of some 15 miles, tend to be arcuate in strike so that the overall pattern gives a scalloped effect. All the faults are downdropped on the north side. Dip separation displacement ranges from a few feet to a maximum of about 40 feet.

The highest peak on Lone Mountain (altitude 9,089) is a small body of Wyman Formation surrounded by quartz monzonite. Rocks in this body strike northeast and dip southeast. Thus the overall picture of Lone Mountain is that of a mass of quartz monzonite in an anticline plunging southeast under General Thomas Hills and chopped off at the northwest end by a series of faults.

Royston Hills

The Royston Hills are a group of low hills separated from the northeast end of the Monte Cristo Range by a narrow valley which is believed to be along a northwest-trending fault (pl. 1). The hills are made up of Triassic Excelsior Formation intruded by quartz monzonite and overlain unconformably by welded ash flows of Tertiary Age. Strikes in the Excelsior, which crop out in two separate areas about 2–3 miles apart, are mostly east-northeast and dips range from gentle to steep. In many places the formation is intensely silicified.

The welded ash flows that crop out over much of the area strike north and dip west. In the southernmost part of the Royston Hills, dips in the ash flows are as high as 70° off the west side of a hill of Excelsior Formation. East of this hill the dips in welded ash flows are also west but at much lower angles, and the volcanic rocks are downfaulted against the Excelsior along the east side of the hill (pl. 1). From these relationships, N. L. Archbold, who mapped the Crow Springs area for the Homestake Mining Co. in 1963, concluded that the entire block of Excelsior Formation and the sequence of welded ash flows to the west has been tilted westward through an angle of several tens of degrees (oral communication, 1964). The field evidence seems amply to justify this conclusion.

MINERAL DEPOSITS

INTRODUCTION

Mining has been the only significant industry of Esmeralda County since the first mineral discoveries in the 1860's. As shown by the fluctuations in the production graph (fig. 10) the industry has had violent ups and downs owing to various economic and political factors. The first recorded production was in 1867, and through 1965 the total value of minerals produced was about $123 million. This figure represents a minimum, however, as it does not include the substantial quantity of gold that was reportedly "high graded" from the Goldfield mines during the peak years of their operation in the early 1900's. Moreover, the price of gold during the principal periods of gold mining was $20.67 per fine ounce, and if the value of gold produced were recalculated at its later price of $35 per fine ounce, the total value of the county's mineral products would approach $200 million.

Although gold has been by far its most important product, Esmeralda County has also yielded at least 24 other mineral substances in commercial amounts, and in addition contains occurrences of still other minerals some of which may eventually be of commercial value. Table 4 gives the deposits and occurrences of economic minerals in the county.

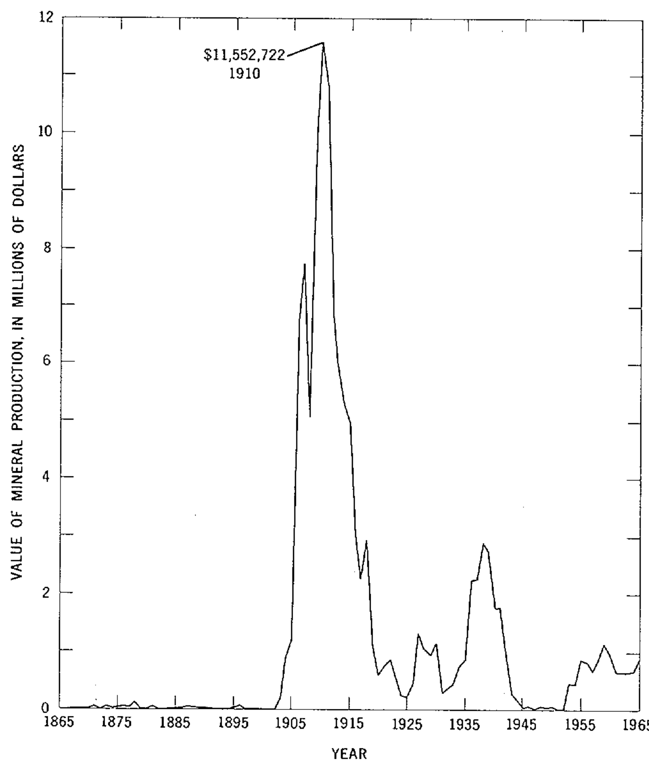

Figure 10. Mineral production by years in Esmeralda County.

TABLE 4. Deposits and occurrences of economic minerals in Esmeralda County.

Metallic mineral deposits and occurrences	Nonmetallic and industrial mineral deposits and occurrences
*Antimony	*Alum and sulfur
Bismuth	*Barite
*Copper	*Borates
*Gold	*Clays
*Iron	*Coal
*Lead	*Diatomite
*Lithium	*Dimension stone
Manganese	Fluorspar
*Mercury	*Gems and gem materials
Molybdenum	Pegmatitic minerals
Rhenium	*Perlite
*Silver	Potassium compounds
Tellurium	*Sand and gravel
Thorium and rare earths	*Silica
*Tungsten	Sodium compounds
Uranium	*Talc and soapstone
*Zinc	

*Recorded production.

Since the mid-1960's diatomite, talc and soapstone, lithium, and sand and gravel for highway maintenance have been the only mineral substances being produced more or less constantly from year to year. Silver, mercury, lead, zinc, gold, bentonite, perlite, and volcanic cinders are produced at irregular intervals.

Table 5 gives the total recorded dollar value of minerals produced in Esmeralda County each year from 1865 through 1966. Figure 10 is a graphic portrayal of these data.

TABLE 5. Mineral Production of Esmeralda County, 1865–1965. Yearly summary.

[Information through 1931 from Couch and Carpenter, 1943, p. 48; for 1932–1952 from U.S. Bureau of Mines Minerals Yearbooks; and for 1953–1965 from files of the Nevada Bureau of Mines and Geology]

Year	*Tons*	*Gross yield*
1865[1]	....	....
1866[1]	....	....
1867	1	$432
1868	5	1,028
1869	11	2,225
1870	76	8,203
1871	403	58,161
1872	24	5,310
1873	304	57,634
1874	618	19,731
1875	946	30,543
1876	850	45,780
1877	725	24,450
1878	1,405	109,142
1879[1]	....	....
1880[1]	....	....
1881	....	59,144
1882[1]	....	....
1883[1]	....	....
1884	200	6,000
1885	1,257	11,919
1886	334	9,813
1887	1,706	44,480
1888	1,975	32,826
1889	290	2,474
1890[1]	....	....
1891	136	5,271
1892[1]	....	....
1893[1]	....	....
1894[1]	....	....
1895	934	17,621
1896	4,449	79,866
1897[1]	....	....
1898[1]	....	....
1899[1]	....	....
1900[1]	....	....
1901[1]	....	....
1902[1]	....	....
1903	1,053	159,446
1904	1,580	880,212
1905	11,419	1,191,236
1906	69,776	6,719,889
1907	76,276	7,781,038
1908	225,646	5,058,548
1909	440,810	9,873,218
1910	511,811	11,552,722
1911	557,386	10,823,913
1912	534,245	6,868,007
1913	540,752	5,881,134
1914	485,538	5,298,179
1915	496,285	4,973,491
1916	381,280	3,009,955
1917	266,764	2,235,716
1918	211,562	2,944,922
1919	28,952	1,087,203
1920	21,383	599,772
1921	21,410	758,126
1922	28,058	871,595
1923	17,342	520,198
1924	14,479	254,062
1925	14,315	206,105
1926	19,787	427,945
1927	82,544	1,320,591
1928	56,987	1,042,961
1929	73,896	932,161
1930	101,206	1,174,418
1931	660	294,907
1932	[2]288,612	[2]519,585
1933	[2]241,363	[2]350,575
1934	[2]395,900	[2]796,839
1935	[2]559,158	[2]975,923
1936	[2]379,506	[2]2,272,697
1937	[2]594,849	[2]2,097,324
1938	[2]647,814	[2]2,694,424
1939	[2]624,241	[2]2,456,047
1940	[2]465,805	[2]1,858,970
1941	[2]187,667	[2]1,770,507
1942	[2]143,024	[2]955,164
1943	[2]23,602	[2]263,984
1944	[2]1,683	[2]54,630
1945	[2]2,738	[2]109,773
1946	[2]1,698	[2]66,502
1947	[2]643	[2]19,799
1948	[2]1,201	[2]66,424
1949	[2]1,505	[2]53,981
1950	[2]2,354	[2]58,895
1951	[2]558	[2]17,304
1952	....	[2]107
1953	....	463,206
1954	....	453,879
1955	....	872,968
1956	....	818,989
1957	....	677,937
1958	....	879,107
1959	....	1,140,441
1960	....	969,741
1961	....	662,113
1962	....	657,669
1963	....	642,283
1964	....	660,649
1965	....	883,094
Total		$122,815,253

[1]No recorded production.
[2]Includes gold, silver, copper, lead, and zinc only.

HISTORY OF MINING

The history of Esmeralda County is to a very large degree the history of mining activity in the county. The county was first settled by men in search of mineral wealth and man's chief endeavor throughout the history of the county has been in the search for and production of minerals. The following brief history of mining is mainly from information in Thompson and West (1881, p. 401–425) and Lincoln (1923, p. 59–84), and various Minerals Yearbooks of the U.S. Bureau of Mines.

Discovery of the famous Comstock Lode in 1859 led to a wave of prospecting that resulted in the finding, chiefly during the 1860's and 1870's, of many mining districts throughout the western part of the Great Basin. One of the earliest discoveries was Aurora in 1860, and the county seat of the original Esmeralda County was for many years located there. The earliest discoveries within the present-day boundaries of Esmeralda County were in 1863 in the Silver Peak district. Other precious metal districts found within a few years were Dyer in 1863–64; Hornsilver, Tokop, and Palmetto in 1866; Montezuma in 1867; Sylvania and Buena Vista in 1870; and Lida in 1871. Other kinds of mineral deposits were also located during this early period of prospecting. These include sulfur and alum in the Alum district, 1868; salt and borax in Columbus Marsh, 1864, and Fish Lake Marsh, 1873; and salt in Clayton Valley, in the 1860's.

By the 1880's the easily mined, enriched, and near-surface gold and silver ores had been largely exhausted and mining activity diminished. Some gold and silver were mined at intervals during the 1880's and 1890's in the Lida, Montezuma, Dyer, and Silver Peak districts, and borax was produced intermittently from Columbus Marsh and Fish Lake Marsh. In 1893 coal was discovered in the low hills south of the present site of Coaldale and 150 tons were apparently mined and sold to the Columbus Borax works.

Discovery of the Klondyke district in 1899 and the subsequent discovery of Tonopah in 1900 led to a new wave of prospecting, with attention directed to the less conspicuous outcrops overlooked by earlier prospectors. Gold was found in the Divide district in 1901, and in 1902 came the discovery of Goldfield, without doubt the single most important event in the history of Esmeralda County. Soon after this, thousands of people were pouring into the area, and about 1910, at the peak of mining activity, the population of Goldfield was 30,000. The boom years at Goldfield extended from about 1906 through 1912 after which production tapered off, slowly at first and then more rapidly. The Silver Peak district was also very productive during the same interval of time.

Districts discovered in later years include the Cuprite district in 1905, the Argentite district in 1920, and the Gilbert district in 1924. During the period 1937–43 the Nivloc mine in the Silver Peak (Red Mountain) district produced over $2 million mainly in silver and was the chief silver producer in the State. Mines in the nearby Silver Peak district during the same interval of time produced over half a million tons of ore valued chiefly for its gold.

The Mohawk mine in the Silver Peak (Red Mountain) district was exploited from 1955 to 1961, and the Ohio mine at Gold Point was active during 1960–61.

Significant exploration activities during the past few years resulted in the development of a body of lead-silver-zinc sulfide ore at the Gold Eagle property, Lone Mountain district, in 1960. This ore was mined in 1965 and 1966. The Sixteen-to-One property between the Nivloc and Mohawk mines in the Red Mountain district was explored by diamond drilling in 1961–62 by the Callahan Mining Co. and further explored in 1963 by a 1,030-foot crosscut by Mid-Continent Uranium Co. A block of silver ore has reportedly been developed, but no production had been realized to the end of 1966. The B & B and other properties in the northern part of the White Mountains produced mercury at times during the late 1950's and early 1960's. Since 1965, one of the world's principal sources of lithium has been developed in Clayton Valley by the Foote Mineral Co. This light metal is produced from brines pumped from wells.

During the post-World War II period, diatomite, talc, and soapstone, rather than precious metals, have been the most important mineral products of Esmeralda County. The Great Lakes Carbon Corp., Dicalite Division (now GREFCO, Inc.), acquired a diatomite deposit at Basalt near the western edge of the county in 1945 and has operated it continuously since the early 1950's. The county has been the principal producer of talc and soapstone in Nevada since production started during World War II. Several mines in the Sylvania Mountains near the California border have been the source.

Esmeralda County contains 30 mining districts, established mostly during the early days of mining activity but some as recently as the 1920's. The district names are shown on plate 2. Some districts have been known by several names; less-used names are shown in parentheses on the figures and in the descriptions of the districts. Some contiguous districts overlap, therefore no district boundaries are shown on plate 2.

In subsequent pages the mineral deposits of the county will be described in summary form on a commodity basis, followed by a description of the various mining districts, and, where possible, important individual mines. The main purpose here is to fit the geology of individual districts into the overall geologic framework of the county. Individual deposits have not been studied in detail although most of those shown on the map (pl. 2) were briefly examined during the course of field work. Much of the following information has necessarily had to come from the existing literature. For additional information the interested reader is referred to the list of "References."

METALLIC DEPOSITS AND OCCURRENCES

Antimony

At least nine occurrences of antimony are known in Esmeralda County but only one, the Mickspot mine along the east flank of the Cedar Mountains near the northern tip of the county, has been a producer. According to Lawrence (1963, p. 66) a small amount of ore was shipped from the Mickspot mine during World War II. The deposit is a vein striking N. 30° W. and dipping 60°–70° SW. in the Excelsior Formation. The vein is 6–14 inches thick and consists of brecciated chert recemented by quartz.

Small pods, veinlets, and single crystals of stibnite occur with quartz, pyrite, arsenopyrite, chalcopyrite, and copper carbonates. The stibnite is oxidized to powdery or vitreous yellow, orange, and white antimony oxides. The deposit is developed by two 35-foot shafts and several small open cuts.

Bismuth

Two districts in the county are known to contain bismuth, although no bismuth has been produced. One is in the bonanza ores of the Goldfield district where bismuth is in the form of bismuthinite(Bi_2S_3) and goldfieldite ($5CU_2S \cdot (Sb, As, Bi)_2(S, Te)_3$). The other is in the Montezuma district where it is associated with base and precious metals in vein and replacement deposits (Cooper, 1962, p. 9). These are in Precambrian and Cambrian rocks intruded by quartz monzonite. Lincoln (1923, p. 78, 79) describes the occurrence as in the Bessler Bros. property, the exact location of which is not known.

Copper

Nearly eight million pounds of copper have been produced from 13 mining districts as a by-product of precious metal mining. Of this total, Goldfield has accounted for nearly 7.7 million pounds, or more than 95 percent. No other district has produced as much as 100,000 pounds. The copper at Goldfield came mainly from the deeper workings. Most of it was contained in the minerals famatinite ($3Cu_2S \cdot Sb_2S_3$), enargite ($3Cu_2S \cdot As_2S_3$), and goldfieldite ($5Cu_2S \cdot (Sb, As, Bi)_2(S, Te)_3$).

Gold

Gold has been by far the most important mineral product of Esmeralda County and has accounted for probably 90 percent of total values produced in dollars. Of this, the Goldfield district has produced the major share, followed by the Silver Peak, Weepah, Divide, and Hornsilver districts. Broadly, the gold deposits are of two types: (1) quartz vein deposits in pre-Tertiary rocks, especially the Wyman Formation near contacts with granitic rock; and (2) deposits in Tertiary volcanic rocks. The Silver Peak (Mineral Ridge area), Weepah, and Hornsilver deposits are good examples of type one; whereas, Goldfield and Divide are representative of type two.

The Goldfield deposits, which have yielded about 4,200,000 ounces, are irregular bodies in silicified, alunitized Tertiary dacite and andesite. A narrow zone about three-fourths of a mile long and dipping gently east contains the principal deposits. Native gold was the principal valuable constituent of both the sulfide and oxide ores (Ransome, 1909a, p. 108). Gold-silver tellurides have also been identified (Tolman and Ambrose, 1934).

The gold particles in all Goldfield ore were typically fine grained but usually visible on close inspection. Much of the finer grained gold was embedded in quartz, and the somewhat coarser particles were commonly embedded in famatinite ($3CuS \cdot Sb_2S_3$). According to Locke (1912, p. 847) the gold amalgamates poorly and is not free milling, possibly due to fineness of grain. The gold-silver ratio averaged about 3 to 1 in the bonanza lodes of Goldfield.

The gold ore of the Silver Peak district consists chiefly of lenticular auriferous quartz veins that replace rather highly folded moderately metamorphosed sedimentary beds of the Wyman Formation. According to Spurr (1906b, p. 37), much of the ore is typically white crystalline quartz which under the microscope is seen to be crowded with liquid inclusions. The gold is usually finely disseminated and in a free state although it is also contained in scattered pyrite and rare galena. Values are not regular. The quartz veins thicken or wedge out irregularly on strike. In places the quartz passes into pegmatitic material or alaskite, leading Spurr (1906b, p. 45) to conclude that the quartz is of the same magmatic origin as the pegmatite and alaskite. The Silver Peak district has yielded more than half a million ounces of gold.

The Weepah and Hornsilver deposits are also in the Wyman Formation. Weepah was discovered in 1904, according to Oxnam (1936, p. 300), but the chief period of activity was during the period 1934–39. The veinlike deposit, as much as 80 feet wide, occupies a shear zone in metamorphosed sedimentary rocks. The Hornsilver deposits are a series of northwest-trending quartz veins, also in the Wyman Formation, whereas the Divide deposits are veins in Tertiary volcanic rocks. These and deposits elsewhere in the county are described more fully in the section on mining districts.

Iron

Iron is known at two localities, the Boak mine in sec. 7, T. 3 N., R. 36 E., in the northwestern part of the county, and the Klondike prospect (not shown on pl. 2) in secs. 19 and 30, T. 1 N., R. 43 E., south of Tonopah. A few tons of iron ore were produced from the Boak mine in 1952 (Reeves and others, 1958, p. 64), but the operation was shut down owing to the difficulty of maintaining a minimum grade of 57 percent iron. Rocks in the mine area are slate and quartzite of the Palmetto Formation, brown dolomite of the Diablo Formation, and conglomerate of the Candelaria Formation. Granitic rock crops out south of the mine area. Iron ore, mainly hematite and some associated magnetite, is in minor shear zones in the dolomite and conglomerate, and as small lenses formed as replacement bodies in the dolomite. Several mineralized areas are exposed in an east-trending belt. The largest area is about 300 feet long and 135 feet wide at the center (Reeves and others, 1958, p. 64). Several smaller mineralized areas crop out farther west. Lenses of nearly pure hematite and partly replaced dolomite and conglomerate are intermixed with small masses of unreplaced country rock.

The Klondike prospect consists of small veins and irregular bodies of specularite a few feet in maximum dimension in the Harkless, Mule Spring, and Emigrant Formations near a contact with muscovite quartz monzonite.

Lead

Thirteen mining districts in Esmeralda County have yielded lead (Horton and others, 1962). Total production is about 6.8 million pounds, of which more than half has come from the Lone Mountain district. Other principal producing districts are Montezuma, Lida, Klondyke, Silver Peak, Tokop, Dyer, and Divide, in descending order of importance. Districts that have produced less than 100,000 pounds include Gilbert, Goldfield, Hornsilver, Palmetto, and Sylvania. Most lead was in the form of sulfide minerals from mines worked principally for their precious metals. An exception is the Gold Eagle mine south of Lone Mountain, which in 1965–66 produced more than 700,000 pounds of lead from a veinlike sulfide deposit.

Lithium

One of the world's principal sources of lithium is Clayton Valley in central Esmeralda County. Since 1965 the Foote Mineral Co. has been producing this light metal from brines pumped through about 15 wells from depths of 300 to 700 feet. The wells are in valley fill. Lithium values occur at different depths in different wells although the depth to water level remains constant at 30 feet in all wells. Temperatures are constant at 70° F.

The brines contain about 400 ppm lithium and also contain sodium, potassium, magnesium, and a little calcium and minor sulfates, according to T. B. Evans, General Superintendent of the operation. The ratio of lithium to potassium is 1:25 and of lithium to magnesium is 1:1.5. The brines are passed through a series of evaporating tanks and thereby upgraded to a concentration of 6,000 to 10,000 ppm lithium. Final processing involves removal of minor impurities. The product shipped is a white lithium carbonate powder having the appearance of fine sugar. The company also plans to recover potassium from the brines when technological problems are solved.

The question of source of the lithium has not been conclusively solved, although geologists employed by the Foote Mineral Co. believe it most likely came from hot springs under the valley, according to T. B. Evans. Alkali Spring on the south side of Alkali Flat, east of Clayton Valley (fig. 1), contains lithium, although Alkali Flat does not. Another potential source of some of the lithium is from lithium-bearing mica in the pegmatites associated with the Mineral Ridge pluton west of Clayton Valley. However this source would seem to be much too small to account for the vast amounts of lithium present in the valley. Moreover, brines in the western part of the valley have a lower lithium content than those in the eastern part. A third possible lithium source might be from volcanic exhalations in Tertiary time. The most likely source of such exhalations would have been the large volcanic center in the Silver Peak Mountains, but there is no evidence that volcanic rocks derived from this source are enriched in lithium.

Manganese

Three manganese prospects are known: the Black Rock prospect in the Silver Peak Mountains, sec. 14, T. 2 S., R. 37 E.; the Dunnigan prospect (not shown on pl. 2) in sec. 23, T. 3 S., R. 42 E., south of Goldfield; and the Gaillac prospect in sec. 2, T. 4 S., R. 42 E. So far as is known none of these prospects has any recorded production.

The Black Rock deposits consist of manganese oxides in pipelike bodies of calcareous and opaline spring sinter. These sinters are in tuffaceous beds within the porphyritic latite. The deposit is relatively inaccessible and low in grade. For further information on the Black Rock prospect the reader may refer to Benson (1950).

The precise location of the Dunnigan prospect is not known and is not shown on the map (pl. 2). The deposit consists of veins containing quartz, psilomelane, and pyrolusite in rhyolitic welded tuff. The veins range from an inch to a foot or two in thickness and extend to a depth of 10 feet or less (Pardee and Jones, 1920, p. 233).

The Gaillac prospect is on a northwest-trending fault zone between Mule Spring limestone and Tertiary welded tuff. The manganese minerals are pyrolusite and psilomelane which occur as nodules as much as 8 inches in diameter (Pardee and Jones, 1920, p. 233). The largest exposed mass of manganese-bearing material is 40 feet long and 6 feet wide and is developed by a shaft at least 60 feet deep.

Mercury

About a dozen mercury occurrences are known in Esmeralda County. Most of these are in the Fish Lake Valley district on the northeast slope of the White Mountains (pl. 2). Other occurrences are in the Montezuma, Alum, and Gilbert districts. Total production from the county is a few thousand flasks, most of which has come from two mines, the B & B and the Red Rock. The mercury deposits are described under the districts mentioned.

Molybdenum

Eleven occurrences of molybdenum are known in Esmeralda County (Schilling, 1962a), but there has been no production (J. H. Schilling, written communication, 1968).

At the Carrie mine in sec. 26, T. 4 N., R. 38 E., Gilbert mining district (pl. 2), molybdenite (MoS_2) occurs in a vein on the 210-foot level with galena, sphalerite, stibnite, and scheelite (Schilling, 1962b, p. 15). The Tonopah Divide mine contains bright-yellow ferrimolybdite(?) ($Fe_2O_3 \cdot 3MoO_3 \cdot 8H_2O$) as aggregates of minute needles on the 165-foot level (Schilling, 1962b, p. 15).

Other occurrences of molybdenite are on the southeast flank of Lone Mountain 14 miles from Tonopah (exact locality unknown); at the Black Horse mine in the Black Horse district (sec. 20, T. 2 N., R. 35 E.) where molybdenite is associated with powellite in tactite; in the Goldfield district where molybdenite occurs at two localities in pre-Tertiary alaskite; at the Bullfrog-George prospect (not shown on pl. 2), Hornsilver district, where it occurs with fluorspar and sulfides in a quartz vein; at the Cucomungo deposit (secs. 2 and 3, T. 7 S., R. 39 E.) 4 miles south of Magruder Mountain where it is disseminated in quartz monzonite; and at the McBoyle prospect, sec. 16, T. 7 S., R. 39 E., approximately at the California-Nevada State line (pl. 2).

The Cucomungo deposit is by far the largest in the county and probably offers the best potential for future development. It lies along a northwest-trending altered zone in quartz monzonite of the Sylvania pluton. The altered zone was traced for several miles along strike and is as much as 1,000 feet wide. In the immediate area of the deposit a block of Wyman Formation is enclosed in the quartz monzonite. The rocks in the altered zone are silicified, sericitized, and argillized. Molybdenite occurs as flakes and rosettes disseminated in the quartz monzonite and also as flakes along the edges of quartz veinlets. Pyrite is present, but copper minerals are virtually absent. According to Schilling (1962b, p. 18), ferrimolybdite(?) is present but difficult to distinguish from other yellow secondary minerals. Abundant dark-blue ilsemannite(?) (a hydrous molybdenum oxide) is forming at the dump of an adit at the lower end of the property and also occurs along a fault zone in the altered area.

At the McBoyle prospect, molybdenite, pyrite, and minor quartz occur along a fault on the contact between marble and quartz monzonite. Ilsemannite(?) and ferrimolybdite(?) stain a 4-inch-wide fault zone in the quartz monzonite in the bottom of the canyon.

The molybdenum-bearing mineral wulfenite ($PbMoO_4$) is apparently present at the Redemption mine, Hornsilver district (Schilling, 1962b, p. 17).

Rhenium

Several hundredths of a percent rhenium has been reported from molybdenite of the Cucomungo deposit in granitic rocks of the Sylvania pluton in the southern part of the county (Schilling, 1964b).

Silver

Esmeralda County has produced something like 12.5 million ounces of silver from the same 15 mining districts that have yielded the gold. The leading producing area has been the Silver Peak district (including Mineral Ridge and the Red Mountain areas) with more than 5 million ounces, followed in descending order by the Divide, Goldfield, Tonopah (within Esmeralda County lines), Lone Mountain (including Weepah), Hornsilver, Klondyke, Lida, and Montezuma districts. The Cuprite, Dyer, Gilbert, Palmetto, Sylvania, and Tokop districts have been relatively minor producers.

Tellurium

Tellurium occurs in gold deposits in the Goldfield and Diamondfield districts (Ransome, 1909a, p. 115–116), although none has been produced. It probably occurs as a gold telluride (Tolman and Ambrose, 1934).

Thorium and Rare Earths

The thorium and rare-earth-bearing minerals, euxenite and samarskite, have been reported from the Lucky Susan No. 1 prospect (not shown on pl. 2) in the White Mountains in the westernmost part of the county (Olson and Adams, 1962, p. 8). This prospect was not located during the course of the present study, but Olson and Adams indicate that these minerals occur in radioactive lenses, probably in pegmatite. No production is recorded.

Tungsten

Small quantities of tungsten have been produced from four localities in Esmeralda County: (1) Rock Hill mine (not shown on pl. 2) north of Columbus Marsh and west of U.S. 95; (2) Black Horse mine southeast of Miller Mountain; (3) Sylvania district; and (4) Copper King (Wylie Green?) mine on the south slope of Gold Mountain (pl. 2). Tungsten is also reported to occur south of Gold Point in the Hornsilver district, in the Monte Cristo Range (probably the Gilbert district), and near "Redlich," a former railroad siding in T. 4 N., R. 36 E., on the boundary between Esmeralda and Mineral Counties.

According to Schilling (1964a, p. 161), the Rock Hill mine in T. 3 N., R. 36 E., is a placer deposit from which scheelite was recovered.

The Black Horse mine yielded tungsten ore in 1942 and also in the early and middle 1950's. It was the county's leading producer of tungsten in 1955 and may have the largest overall production. However, the grade is low. Scheelite and some powellite are disseminated in small amounts in tactite in the Harkless(?) Formation. The tactite is in layers that are 20 to 60 feet thick and strike a little north of east.

Tungsten occurs in a number of localities in the Sylvania district, and three deposits (Schilling, 1963a) have a small recorded production, apparently in 1943 and in the early 1950's. Most of the deposits are in a belt of Wyman Formation lying largely within the Sylvania quartz monzonite pluton. Some deposits consist of small amounts of scheelite in bodies of tactite. Others are veinlike quartz containing huebnerite associated with fluorspar and pyrite (D. M. Lemmon, written communication, 1967).

The Copper King mine on the south slope of Gold Mountain was not identified during the present study but may be the same as the Wylie Green mine (pl. 2). If so, the tungsten is in tactite of the Wyman Formation adjacent to a quartz diorite contact. The size of the diggings indicates that production must be very small.

Uranium

Five occurrences of uranium are known in Esmeralda County (Butler and others, 1962, p. 15; Schilling, 1963b). No production has been reported. The occurrences are the Silver Queen and Garibaldi claim group in secs. 29 and 32, T. 3 N., R. 32 E., about 3 miles west of Tonopah; a deposit near Coaldale in sec. 33, T. 2 N., R. 37 E., south of Coaldale; the Gap Strike and other claim groups at the northwest end of the Silver Peak Mountains, secs. 3 and 10, T. 1 N., R. 36 E.; the Jet claim group south of Lone Mountain, secs. 24, 25, 35, and 36, T. 1 N., R. 40 E.; and the Checkmate prospect between Slate Ridge and Gold Mountain, T. 7 S., R. 42 E. (pl. 2).

The Silver Queen and Garibaldi group are in the Siebert Tuff. According to Wood (1956, p. 536) uraniferous collophane and uraniferous opal are disseminated in stratified tuff and diatomaceous earth and in opal lenses. Davis and Hetland (1956, p. 355) state that anomalous radioactivity extends over an area a mile wide and 8 miles long, and within this area are local concentrations of higher radioactivity. These authors believe that the deposit is of hypogene origin, localized by a northward-trending basin and range-type fault. No ore has been produced from these deposits (Larry Garside, written communication, 1968).

The prospect near Coaldale is in rhyolitic welded tuff that contains veinlets and small irregular pods of higher grade uranium rock (Duncan, 1953, p. 1). The conspicuous ore minerals are autunite ($Ca(UO_2)_2P_2O_8 \cdot 8H_2O$) and phosphuranylite ($(UO_2)_3P_2O_8 \cdot 6H_2O$), which coat some fractures and partly fill some feldspar crystal cavities in the tuff. Uranium is also present in small amounts in siliceous material that occurs as scattered veinlets and as matrix of a breccia pipe. Numerous limonite-stained joint surfaces on the welded tuff also contain small amounts of uranium. Several samples collected by Duncan (1953, p. 1) from weathered outcrops contained from 0.002 to 1.86 percent uranium.

According to A. J. Ranbosek (written communication, 1955), the Jet prospect is in a shear zone cutting rhyolitic rocks. The radioactive minerals are unidentified.

The Gap Strike prospect consists of secondary uranium minerals disseminated in tuffaceous rocks and ferruginous sandstone (D. L. Hetland and D. F. Erich, written communication, 1955).

The Checkmate prospect is a vein in limestone (D. L. Hetland and H. J. Paluch, written communication, 1954). The vein contains 0.14 percent equivalent U_3O_8.

Zinc

Nearly a million pounds of zinc have been produced in Esmeralda County from three mining districts — Lone Mountain, Silver Peak, and Hornsilver (Horton and others, 1962). Of this total, the Lone Mountain district has accounted for all but about 19,000 pounds. All the zinc produced prior to 1965 was a by-product of precious-metal mining. However, in 1965 and 1966 some 900,000 pounds of zinc, along with equally significant amounts of lead and silver, were taken from the Gold Eagle mine south of Lone Mountain. This mine is a veinlike sulfide deposit within the contact aureole of the Lone Mountain pluton.

NONMETALLIC AND INDUSTRIAL MINERAL DEPOSITS AND OCCURRENCES

Alum and Sulfur

A deposit of alum and sulfur, discovered in 1868, occurs at Alum about 11 miles north of Silver Peak on a low divide between Clayton Valley and Big Smoky Valley (pl. 2). Spurr (1906b, p. 157) described the deposit as being in an elongated dikelike or necklike mass of rhyolite having the appearance of being intrusive into gently folded white and red sedimentary rhyolitic tuffs of Tertiary Age. In the southern part of the area the decomposed rhyolite shows sulfur coating all cracks and crevices over an area 200 feet in diameter. The alum, determined to be ordinary potassium alum kaolinite ($K_2O \cdot 3Al_2O_3 \cdot 4SO_3 \cdot 6H_2O$) containing about 11.4 percent K_2O, is closely associated with the sulfur but forms veins and stringers as much as several inches thick that split and ramify throughout the altered rhyolite. In places the alum veins tend to conform to a sheeting in the rhyolite that strikes about north and dips moderately east. Bright red stains associated with the alum and sulfur were thought by Spurr (1906b, p. 157) to be cinnabar but were not positively identified. The deposit is probably of solfataric origin. Attempts were made to work the deposit in 1921 and 1939, but they were largely unsuccessful. An attempt was being made during 1967 to develop the property (K. G. Papke, written communication, 1968), but the results of this work are not known. The deposit is developed by a pit and by a shaft inclined about 35° toward the east.

Sulfur occurs also at two localities in the Cuprite district about 12 miles south of Goldfield (Ransome, 1909a, p. 109–110; Branner, 1959). These deposits occur as irregular seams and blebs in altered Tertiary sedimentary rocks and welded tuffs. A "car or two" of sulfur is said to have been shipped from several prospect pits prior to 1909 (Ransome, 1909a, p. 110), and ore was also shipped for use as a soil aid from 1915 to 1923 (Branner, 1959).

Sulfur occurs also as a secondary gangue mineral in silver-bearing veins in the Klondyke district 10 miles south of Tonopah (Ball, 1907, p. 81).

During recent geologic mapping of the county, sulfur was also seen at the Riek mercury property, secs. 11 and 14, T. 1 S., R. 35 E., Fish Lake Valley district; and in a canyon a few hundred feet northwest of the Silver Mountain prospect, sec. 31, T. 8 S., R. 41 E., Tokop district. At the Riek property sulfur occurs as irregular stringers along fractures in the tuffaceous country rock and also as small disseminated blebs; at the locality near the Silver Mountain prospect it occurs as veinlets in marble of the Wyman Formation.

Barite

Barite has been produced from three deposits in Esmeralda County, and at least two additional prospects are known. Two of the productive deposits are a little over a mile apart in the Weepah Hills. One is in the eastern part of sec. 31, T. 1 N., R. 40 E., and the other is in the southeast part of sec. 29, T. 1 N., R. 40 E. The first of these two is probably the American Barite mine described by Hewett and others (1936, p. 150) and Horton (1963, p. 9), although in Hewett and others it is incorrectly located (stated to be on the *west* side of Lone Mountain in sec. 34, T. 1 N., R. 40 E.). The deposit is a vein type about 2 feet thick — probably along a small flat thrust in a limestone of the Harkless Formation. The barite is coarsely crystalline and in places rather extensively replaces the limestone. Pyrite and galena are associated with the barite. According to Horton (1963, p. 9), the American Barite mine yielded about 1,000 tons of barite during the period 1907–19.

The second deposit in the Weepah Hills is a little over a mile to the northeast of the one described above. It is in limestone along a thrust fault between Harkless Formation (upper plate) and Poleta Formation. Streaks of disseminated galena are present locally in the barite which appears to be a replacement of limestone. The property is developed by a fairly large open cut, but the amount of barite produced is not known. Old newspapers found on the property indicate that the deposit was probably being mined during the late 1940's.

A third deposit in the county that has produced barite is the King and Queen deposit on Miller Mountain near the Mineral County border. Horton (1963, p. 8) gives the location of this deposit as sec. 23, T. 2 N., R. 34 E. However, it was not located in the field during the present study and is not shown on the map (pl. 2). Horton (1963, p. 8) states that the deposit is in limestone (possibly Poleta) in the form of 3- to 6-foot thick veins. It is developed by short adits, stopes, and open cuts. Estimated production is 100 to 500 tons.

Two barite prospects with no recorded production are the Congress, 5 miles south of Goldfield, in sec. 34, T. 3 S., R. 42 E., and the Heavy Rock in the Silver Peak Mountains in sec. 8, T. 4 S., R. 38 E. Horton (1963, p. 9) describes the Congress occurrence as consisting of "... small pods and lenses along bedding planes and faults in a cherty limestone." The limestone is probably Mule Spring or Emigrant. The property is developed by small pits and cuts. The Heavy Rock prospect shows barite as a replacement of chert of the Palmetto Formation. The barite is exposed in small pits.

Borates

Borate minerals have been produced from three areas in Esmeralda County: (1) Columbus Marsh; (2) Fish Lake Valley Marsh; and (3) east of Fish Lake Valley Marsh. A fourth deposit at Cave Spring has no commercial value. Total production from Esmeralda County is not known but is probably less than $900,000.

The first production was from Columbus Marsh, which was located as a salt deposit in 1864 (Lincoln, 1923, p. 62). The borate mineral ulexite (cotton ball) ($NaCaB_5O_9 \cdot 8H_2O$) was discovered in 1871 and within a few years a number of treatment plants were active. According to Smith (1964, p. 184), cotton ball forms thin layers 1 to 6 inches below the surface in mud, silt, and sand in irregular areas around the margin of the playa.

Borax ($Na_2B_4O_7 \cdot 10H_2O$) was produced from Fish Lake Valley Marsh as early as 1873 (Lincoln, 1923, p. 66). In 1875, Pacific Borax Co. moved its plant to Fish Lake Valley from Columbus, and borate deposits were worked for a number of years thereafter. Two plants were operative; the borax was extracted from ulexite in salty ground along the east margin of the marsh.

Ulexite was also mined in 1939 from deposits in Tertiary sedimentary rocks 3 miles east of the Fish Lake Marsh deposit. About 200 tons of B_2O_3 were produced at this time. The ulexite occurs mainly as veinlets and "cotton ball" aggregates.

The Cave Spring locality is known to contain the mineral searlesite ($NaBSi_2O_6 \cdot H_2O$) in very thin veinlets. The occurrence is mainly of mineralogical interest (Foshag, 1934) and is of no commercial value.

Clays

Mined or prospected clay deposits are known in four widely separated localities in Esmeralda County, but only two have yielded commercial quantities. The deposits are: (1) President clay deposit near Dyer in Fish Lake Valley (exact location unknown and not shown on pl. 2); (2) Blanco mine on northeast flank of Silver Peak Mountains, sec. 22, T. 1 N., R. 37 E.; (3) Tonopah (Lambertucci) clay deposit west of Tonopah, sec. 32, T. 3 N., R. 42 E.; and (4) Cuprite clay deposit about 12 miles south of Goldfield (exact location unknown and not shown on pl. 2).

Little is known of the President clay deposit. According to Minerals Yearbook (1960, p. 654), Nevada Clay Products conducted maintenance and some development in 1960, but no production or sales were reported.

The Blanco deposit (pl. 2), operated by R. T. Vanderbilt Co., Inc., according to Olson (1964a, p. 188), yields a montmorillonite (bentonitic) clay for use in the company's line of Veegum products. The mine was operated during the period 1963–65. The deposit is in a hydrothermally altered welded tuff and may be spatially related to a northeast-trending fault.

The Tonopah kaolin clay deposit, also known as the Lambertucci deposit, is, according to Olson (1964a, p. 188), an alteration product of tuffaceous beds in the Siebert Tuff. The beds are slightly less than 2 feet thick, probably too thin and areally limited to make their utilization likely in the near future.

Olson (1964a, p. 188) states that at the old mining district of Cuprite, clay derived from altered (Tertiary) tuffs once was shipped to Los Angeles as china clay for the manufacture of sanitary porcelain. The clay has not been identified mineralogically, but the use to which it was put strongly indicates that it was the kaolin type.

Coal

In 1893 coal was discovered in Tertiary sedimentary rocks in an area at the northeast end of the Silver Peak Mountains known as the Coaldale district. The coal is mainly in the southern part of T. 2 N., R. 37 E. Four beds containing coal have been recognized. They range from about 4 feet to as much as 21 feet thick, according to Hance (1913, p. 315), and are distributed over a stratigraphic interval of about 290 feet. The rock between the coal-bearing beds is sandstone, tuff, and rhyolite. The beds strike generally northwest and dips range from about 20°-40° northeast. According to Spurr (1904, p. 290), some of the beds can be traced for 3,000 to 4,000 feet along strike. However, they are cut by a number of faults.

Material in the coal beds ranges from black shale to coal having a fairly brilliant luster. In general, coal in the upper two beds is dull whereas that in the lower two beds has a more brilliant luster. Ash content of even the best grade of coal is high. Local variations are pronounced, and lenses of good coal are usually of small extent (Hance, 1913, p. 316). The aggregate of coal in an exposed section may amount to 2 or 3 feet, but it is usually made up of thin streaks.

Attempts to mine and market the coal locally were made at various times in the 1890's and early 1900's, but because of the poor quality none were very successful.

Diatomite

Diatomite occurs at several localities in Esmeralda County, including one on the north slope of the Palmetto Mountains, one about a mile west of Tonopah, one in the western part of the Monte Cristo Range, one in the Weepah Hills, and one about 20 miles west of Coaldale on the boundary between Esmeralda and Mineral Counties just south of U.S. Highway 6. Only the one near the Esmeralda-Mineral County line is shown on plate 2. All the deposits are of Miocene or Pliocene Age.

The deposit astride the Esmeralda-Mineral County line is the largest and the only one from which diatomite has been produced. It is operated by GREFCO (Great Lakes Carbon Corp.) and is one of the principal producers of diatomite in Nevada. The following paragraphs, kindly furnished by J. S. Horton, Chief Mine Engineer of the Corporation, to the Nevada Bureau of Mines and Geology, describe the deposit:

> "Great Lakes Carbon Corporation has been operating the Basalt diatomaceous earth quarries since 1944. The deposit straddles the Esmeralda-Mineral County line near Basalt Junction, Nevada. The property covers some 2,500 acres adjacent to U.S. Highway 6 and is in T. 2 N., R. 33 E., and T. 2 N., R. 34 E., Mount Diablo Base and Meridian.
>
> "The deposit is an isolated embayment of a large fresh-water lake bed of the Tertiary period. During the interval of diatomaceous deposition there was a minimum of contaminants introduced by interior drainage into this embayment.
>
> "Structurally the deposit forms a shallow basin in the western sector while the central and eastern zones are monoclinal. Stratigraphically the lacustrine sediments are composed of diatomite, argillaceous diatomite, calcareous diatomite, clay, sand and volcanic ash. This lacustrine section overlies basalt and andesite flows, and is itself overlain by basaltic flows.
>
> "Species of diatoms occurring in this deposit are fresh-water structure, Melosira predominating. More specifically the more abundant species are *Melosira granulata, Stephanodiscus aslraea,* and *Eunotia robusta.*"

Dimension Stone

Stone was quarried on a small scale in the late 1800's and early 1900's for local construction prior to the development of the western cement and brick industry. The Esmeralda County courthouse and one or two other buildings in Goldfield are built of welded tuff from the Spearhead Member of the Thirsty Canyon Tuff, but no dimension stone industry ever developed in the county.

Fluorspar

Three occurrences of fluorspar are known in Esmeralda County (Horton, 1961) although apparently no fluorspar has been produced. The Flora prospect is reported to be in sec. 28, T. 4 N., R. 36 E., in the northern part of the county. It was not located during the course of this study and is not shown on plate 2. Quartz veins apparently as much as 30 feet wide in granodiorite contain sulfides and in places considerable fluorite (Horton, 1961, p. 11).

The Amry prospect (Horton, 1961, and information in files of the Nevada Bureau of Mines and Geology), sometimes known as the Sorenson, is in sec. 4, T. 7 S., R. 39 E., but was not located during the present study and is not shown on plate 2. The country rock is granite containing a small pendant of calcareous rock (probably Wyman Formation) about 300–500 feet wide and 1,000 feet long. Fluorspar formed in a narrow steep fracture zone between garnetized rock and partly replaced limestone. Fractures strike N. 55 W., dip steeply, and show fluorspar for a strike length of 50 feet.

The Bullfrog-George prospect is in T. 7 S., R. 41 E., southwest of Gold Point but was not located during this study and is not shown on plate 2. Ball (1907, p. 194) states that the prospect is on the side of a domical granite hill and that the deposit is a quartz vein 4 to 9 feet thick traceable for about a quarter of a mile. The vein strikes N. 70° W. and is vertical. The quartz contains some sulfides, including MoS_2, and is in places intensely crushed. Purple fluorspar occurs in crevices in the quartz, and cubes of fluorspar one-fourth inch in diameter line vugs in the quartz.

Gems and Gem Materials

The Following gem materials are known to occur in the county: turquoise, variscite, agate, jasper, opalite, Apache tears, petrified wood, chalcedony, obsidian, and barite. Most of these materials are collected by hobbyists and weekend prospectors. Turquoise (Murphy, 1964; Morrissey, 1968) is the only gem material that has been produced by conventional mining enterprises.

According to Murphy (1964, p. 206; map p. 204) turquoise occurs with variscite in four main localities, as follows: (1) Candelaria-Sigmund group (not shown on pl. 2) in Candelaria Hills; (2) Los Angeles Gem Co. group (not shown on pl. 2) in Candelaria Hills; (3) Coaldale mining district northwest of Coaldale Junction; (4) Carr-Lovejoy group (not shown on pl. 2) in east-central Monte Cristo Range. Production from each of these areas is known to be less than $500,000.

Turquoise, without variscite, is known in four additional localities: (1) Crow Springs (Royston) mining district in extreme northeastern part of county; (2) Lone Mountain mining district in General Thomas Hills; (3) Klondyke mining district; (4) Goldfield mining district.

The Royal Blue mine (pl. 2) in the Crow Springs (Royston) district is, according to Murphy (1964, p. 206), one of the most important turquoise mines in Nevada. This mine is listed, apparently in error, as being in Nye County, Nev., by Morrissey (1968, p. 26). The mine had reportedly produced more than $5 million in turquoise by about 1915 and was also active during the 1930's and 1940's. It was worked by five short adits, three shallow shafts, and open cuts. Murphy (1964, p. 206) states that the "turquoise occurs as veinlets, seams, and occasional nodules in fracture zones in altered trachyte and porphyry." Color ranges from dark sky blue to pale blue. It was generally of high quality although some exhibited a greenish cast.

The Lone Mountain (Valley View?) turquoise deposit is in sec. 18, T. 1 N., R. 41 E., in the heart of the General Thomas Hills. The deposit was discovered in 1920 and worked from 1927–35 and again in 1954–55. Total production is unknown but apparently was over $500,000. U.S. Bureau of Mines Minerals Yearbook states that 2,900 pounds of turquoise valued at $43,500 were produced in 1954. An appreciable quantity of high-grade turquoise was also produced in 1955, according to the same source.

The deposit is developed by a 60° inclined shaft at least 200 feet deep that starts in shale of the Ordovician Palmetto Formation but which may penetrate Cambrian rocks at depth. The shale rests as a thrust plate on the Cambrian. The turquoise occurs as nuggets of solid, light-blue material in the harder shales and as spiderweb material in the softer clays (Murphy, 1964, p. 206). The material, noted for its stability of color, is unusually hard.

Pegmatitic Minerals

Pegmatites containing quartz, feldspar, and mica occur in granitic rocks of the Lone Mountain, Mineral Ridge, Palmetto, and Sylvania plutons (Ball, 1907, p. 53, 192–193, and 185; Spurr, 1906b, p. 22–26, 129–156; Olson and Hinrichs, 1960, p. 182–184), and in Precambrian metasedimentary rocks on Mineral Ridge (Olson and Hinrichs, 1960, p. 182–183). Beryl is reported from a pegmatite in the Sylvania district (Olson and Hinrichs, 1960, p. 183) and lepidolite from a pegmatite on Mineral Ridge (Bailly, 1951, p. 85–86; Olson and Hinrichs, 1960, p. 183). No production is known from these pegmatites.

Perlite

Perlite occurs at numerous localities in the county, commonly as selvage zones between rhyolite or quartz latite plugs and domes and the adjoining intruded or underlying rocks. Only one deposit — that in the Monte Cristo Range, sec. 5, T. 4 N., R. 39 E. -- has been mined. The operation was carried on in 1964–65 by Perlex Products Corp., owned by E. T. Brown of Salinas, Calif. A selvage zone between rhyolite and welded tuff is made up of good "popping" perlite containing obsidian (Apache) tears that make up from 5 to 75 percent of the rock. In 1964, according to Mike Hammer, who was in charge of the operation, the Apache tears were being mined and stockpiled for sale and eventual use in terazzo tile.

The Minerals Yearbook for 1963 indicates that the Perlex Corp. also owns a deposit in the Fish Lake Valley district (Hurry Up claims), but the exact location is unknown. Apparently there has been no production from them.

Potassium Compounds

Potassium salts have been detected in the brines and the water-soluble part of playa deposits at Columbus Marsh (Gale, 1912; Hicks, 1915; Phalen, 1919, p. 142) and at Silver Peak (Clayton Valley) Marsh (Dole, 1911; Phalen, 1919, p. 142–145). The amount of these salts is small. The water-soluble part of muds from one well at Columbus Marsh was 2.84 percent, of which 5.17 percent was potassium salts. At Silver Peak Marsh, salt that crystallized in surface pits contained 1.26 percent potassium chloride. No production of potassium salts has been reported in the county.

Sand and Gravel

Sand and gravel are of common occurrence in the county, and use is almost entirely in highway construction and maintenance. Small gravel pits, worked by the highway department as the need arises, are strategically located near highways at several places in the county.

Silica

According to Fulton and Smith (1932), quantitites of silica were produced from the Cuprite district (pl. 2). Large deposits are associated with alunite and sulfur. All known production was in the period 1914–18. In 1960 (Olson, 1964b, p. 245), an attempt was made to mine and process silica from hydrothermally leached volcanic rock in the hills northeast of Lida Junction just south of the Cuprite district. The operation was inactive in 1964.

Sodium Compounds

Sodium salts occur at Columbus and Silver Peak (Clayton Valley) Marshes. Surface shows of salt occur along the margin of Columbus Marsh, although test drilling by the U.S. Geological Survey failed to disclose any salt beds or concentrated brines beneath the surface (Gale, 1912; Hicks, 1915; Phalen, 1919, p. 142). Practically the entire surface of Silver Peak Marsh, which has an area of 32 square miles, is covered with a layer of salt about one-fourth of an inch thick. It is estimated that not less than 15 square miles of the northeastern portion of the marsh contains a 10-foot-thick saline bed, of which at least 60 percent is salt, representing a salt reserve of 15 million tons lying within 40 feet of the surface (Dole, 1911; Phalen, 1919, p. 142–145). No production of sodium compounds has been reported in the county.

Talc and Soapstone

Virtually all the talc produced in Nevada (Chidester and others, 1964, p. 35–37) has come from the Sylvania district in an area of a few square miles along the southwestern border of Esmeralda County, mostly in T. 5 and 6 S., R. 38 E. (pl. 2). At least 29 talc mines and prospects are present in this area, the largest being the Reed, Oasis, Roseamelis, and White Eagle mines. Approximate total production of the area from 1941 through 1963 was 186,136 short tons, according to data tabulated by K. G. Papke of the Nevada Bureau of Mines and Geology from reports of the U.S. Bureau of Mines. Part of this was steatite grade. Production prior to 1941 was something more than 10,000 tons.

Two main types of talc are recognized in the area — white ore and blue ore. The white ore is described by B. M. Page[1] as practically white but tinged with pale green. It is fine grained, lacks any fibrous, radiating, or foliate texture, and is soft and slippery. Most commonly it is found in a highly fractured condition, but in places it is in solid masses. Analyses by the U.S. Bureau of Mines show it to contain less than 1.5 percent iron oxide and 1.5 percent lime; hence, it is probably of steatite grade.

The term "blue ore" is used by operators indiscriminately for at least three materials, only one of which appears to be talc. Dark-gray talc with a supposedly bluish tinge is one of the blue ores of the area. It is massive, soft, and slippery and is not as abundant as the other materials which come under the same popular local designation. Some of the dark-gray talc may possibly be steatite. Other varieties of blue ore are impure talc, containing as much as 2.79 percent iron oxide and 18.18 percent alumina, and a material that is greenish rather than blue and which is, in the main, chlorite.

Most of the larger talc deposits in the southern part of the area are along an irregular thrust fault having porphyritic quartz monzonite in the upper plate overlying Wyman Formation and Reed Dolomite (pl. 1). This thrust was called the Palmetto-Oasis thrust by Ben M. Page. An altered zone ranging from several to many feet thick along the thrust is mostly filled with chlorite, talc, and partly altered fragments of country rock but in places contains irregular to podlike masses of talc 50 to 500 feet in exposed length, 1 to 30 feet thick, and 50 to 100 feet downdip. The thickest talc bodies seem to be in areas where the dip of the fault is flat or gentle, and the ore tends to thin out in areas where the dip steepens. Although the general distribution of the talc is controlled largely by the thrust fault, much of it lies wholly within the Reed Dolomite 50 to 200 feet from the thrust. Some talc bodies in the southern part of the area seem to bear no relation to the thrust. The talc is thought to have formed by hydrothermal solutions rising along the fault from magmatic sources at depth. Some of the necessary magnesia was already present in the dolomite, but the hot solutions contributed still more, along with silica and water; calcium carbonate of the main host rock (Reed Dolomite) was removed.

The deposits in the northern part of the area are more sparsely distributed and apparently smaller than those in the southern part. They also lack a single prime ore control comparable to the Palmetto-Oasis thrust. Most of the deposits are in the Lower Cambrian Poleta and Harkless Formations. They commonly are lenses and have hornfels on at least one side.

[1]Much of the data in this section are taken from an unpublished report by B. M. Page who mapped and studied the deposits for the U.S. Geological Survey in 1942.

MINING DISTRICTS

Alum District

The Alum district is about 11 miles north of the town of Silver Peak in the central part of the county. Here alum and sulfur, and possibly cinnabar, occur in Tertiary rhyolite. This deposit is described on page 60.

Black Horse District

The name Black Horse district is sometimes used to describe an area that includes the Black Horse mine southwest of Miller Mountain in the northwestern part of the county. This mine may have the largest production of tungsten in the county and is described on page 59.

Buena Vista (Oneota, Basalt, Mount Montgomery) District

The Buena Vista district, which has also been called the Oneota, Basalt, or Mount Montgomery district, is on the west flank of the northernmost part of the White Mountains, partly in Mineral County and partly in Esmeralda County. The county line is so poorly located in that area that some of the mines shown as being in Mineral County (Ross, 1961, pl. 1) could actually be in Esmeralda County. On plate 2 only those mines that are definitely in Esmeralda County are shown and none is the same as on the map of mineral deposits in Mineral County (Ross, 1961, pl. 1).

In Esmeralda County, most of the deposits in the district occur in a northwest-trending outcrop of the Palmetto Formation (Ordovician) within a mile of the Inyo batholith. These deposits are apparently mostly silver-gold veins, although mercury and tungsten deposits occur in the district in Mineral County (Lincoln, 1923, p. 140; Ross, 1961, p. 80), and some mines contain lead or copper minerals as well. Recorded production from the district in Esmeralda County is 1,524 tons worth $13,707 (table 6).

Coaldale District

This district lies a few miles south of Coaldale and consists primarily of poor quality coal deposits in Tertiary sedimentary rocks (see p. 61). Sometimes included in this district are small deposits of variscite and turquoise from Tertiary volcanic rocks at the south end of the Monte Cristo Range (Lincoln, 1923, p. 60–61).

Columbus Marsh District

Columbus Marsh is in the northwestern part of the county, west and northwest of Coaldale. It has produced some borate minerals (see p. 61) and contains some salt deposits and noncommercial amounts of potash (Lincoln, 1923, p. 62).

Crow Springs (Royston) District

The Crow Springs district is in the Royston Hills in the northern part of the county. It continues northeastward to the Esmeralda-Nye County line. Mineral deposits adjacent to the county line in Nye County are in the Royston district, and this district name is sometimes applied also to deposits in Esmeralda County. According to Lincoln (1923, p. 62–63), the district consists primarily of turquoise mines, although he notes that some diatomaceous earth, silver, lead, copper, and gold also occur in the area.

TABLE 6. Summary of mineral production by districts to 1960.

[Information through 1931 from Couch and Carpenter, 1943, p. 49–52; for 1932–57 from U.S. Bureau of Mines Minerals Yearbooks, and for 1958–60 from files of Nevada Bureau of Mines and Geology. Information for Goldfield district from files of Nevada Bureau of Mines and Geology and from U.S. Bureau of Mines Minerals Yearbooks, 1932–57]

District	Tons	Gross yield
Buena Vista (Oneota, Basalt, Mount Montgomery)	1,524	$13,707
Diamondfield	1,806	52,305
Divide (Gold Mountain)	122,994	3,503,641
Dyer	281	12,817
Fish Lake Valley (White Mountain)	2,196	51,681
Gilbert (Desert)	4,465	104,960
Goldfield	7,740,154	89,774,317
Good Hope (White Wolf)	69	1,795
Hornsilver (Lime Point, Gold Point)	57,775	736,609
Klondyke (Southern Klondyke)	2,758	67,352
Lida (Alida, Tule Canyon)	5,573	326,391
Lone Mountain (West Divide, Weepah)	248,991	1,382,693
Montezuma	2,461	223,663
Palmetto and Windypah (Fesler)	319	14,686
Railroad Springs	56	4,568
Silver Peak (Red Mountain, Mineral Ridge, Argentite)	2,102,830	16,312,849
Sylvania (Green Mountain)	347	19,881
Tokop (Gold Mountain, Oriental Wash, Bonnie Claire)	239	3,985
Tonopah (within Esmeralda County lines)	626,979	2,593,301
Unknown	262	18,020

In the district, turquoise occurs 1 mile southwest of Crow Springs (Morrissey, 1968, p. 7), 2 miles east of Crow Springs (Morrissey, 1968, p. 7), and in the Royal Blue mine near the Esmeralda-Nye County line (Murphy, 1964, p. 206). The Royal Blue mine is shown, apparently in error, by Morrissey (1968, map) as being in Nye County. Of these three properties, the Royal Blue mine is the most important and has reportedly produced more than $5 million in turquoise (see section on "Gems and Gem Materials"). It is in altered trachyte and porphyry (Murphy, 1964, p. 206). The deposit southwest of Crow Springs occurs in quartzite and tuffaceous(?) units, apparently part of the Excelsior Formation, and the deposit east of Crow Springs is in quartz monzonite.

In 1963, Homestake Mining Co. drilled several holes in altered granitic rocks and adjacent welded tuffs in sec. 36, T. 5 N., R. 39 E. This search was for a disseminated copper deposit, but the results were negative.

Cuprite District

The Cuprite district is along Mount Jackson Ridge 12 to 15 miles south of Goldfield. Heavy metal in the district is mostly copper, although silver, gold, and lead also occur (Ball, 1906, p. 59–61; 1907, p. 69–71). According to Ball (1907, p. 70), "chalcopyrite and less pyrite, galena, calcite, and quartz appear to have been deposited as sporadic masses in the limestone as seams along joints and as lens-shaped bodies along shear zones." These ores were "altered by aqueous solutions to chalcocite, carbonates, and oxides, the secondary ores in large part replacing limestone." The limestone is apparently in part the Mule Spring Limestone (Lower Cambrian) and the Emigrant Formation (Middle and Upper Cambrian). Ball also mentions gold-bearing veins in Tertiary rhyolite (probably mapped as welded tuff on our plate 1) in the northeast end of the district. Sulfur occurs in altered Tertiary tuffaceous sedimentary rocks and welded tuffs at the northeast end of the district (Ransome, 1909a, p. 109–110). Production from the district is apparently very small, and none has been recorded.

Diamondfield District

This district is about 5 miles northeast of Goldfield in the northern segment of the elliptical belt of altered rock described in the section on the Goldfield district. The district is a little over a mile long, and the western part is characterized by quartz-alunite ledges that trend east and dip nearly vertical. They are enveloped by argillized Milltown Andesite. Not much detail has been published on Diamondfield, but apparently the ore bodies in the western part of the district were irregular, plunged steeply, and contained free gold as the ore mineral and very little silver. In contrast, the ore bodies at the eastern end of the Diamondfield district, were along a nearly flat fracture zone in highly silicified dacite and contained a much higher percentage of silver than any other ores in the entire Goldfield area. Total recorded production of the Diamondfield district is $52,305, but actual production may be as much as $1 to $2 million.

Divide (Gold Mountain) District

The Divide district (also called Gold Mountain district), centering about 5 miles south of Tonopah (pl. 1), has been principally a silver-producing district although the earliest work, dating back to 1902, was on a small gold vein. Silver was discovered in 1917, and the district was active after that for about 30 years. Total production has amounted to $3,503,641, and the district ranks third in Esmeralda County behind Goldfield and Silver Peak as a mineral producer. The principal mine has been the Tonopah Divide.

The district lies entirely in rocks of Tertiary Age and most of the rocks are of volcanic origin. The principal host rock, the Fraction Breccia, is overlain in places by the Siebert Tuff and intruded and (or) overlain in the general area by plugs and domes of Oddie(?) Rhyolite, Divide Andesite, and quartz latite. The Fraction Breccia may be underlain by pre-Tertiary rocks, or by the Mizpah Trachyte and older Tertiary rocks as it is at Tonopah. According to Knopf (1921, p. 147), who has made the principal study of the district, the ore bodies are zones of fracturing and shearing in the Fraction Breccia and, strictly speaking, are lodes rather than veins. The walls of the lodes are generally well defined, and at least some of them can be demonstrated to mark zones of faulting. The Tonopah Divide lode strikes northwest and is vertical. Some of the other mineralized zones have this same trend, according to Knopf (1921, p. 158), but still others strike at various azimuths.

Outcrops of the lodes were lightly iron stained by disseminated limonite and were usually barren or nearly barren of silver. Pyrite occurred below the level of oxidation in the lodes and also in the wallrocks. Lode matter in places was netted with a few thin, short veinlets of fine-grained quartz, but the scarcity of quartz is in marked contrast to the siliceous ores of the Tonopah district a few miles to the north. A characteristic feature of the Tonopah Divide lode, according to Knopf (1921, p. 159) is that it was cut by layers of white sericite ranging from a thin film up to several inches thick. Hornsilver was visible in many places in these sericite layers, and silver assays up to hundreds of ounces per ton were common.

The silver in the lodes of the Divide district was chiefly in the mineral cerargyrite which in the main was finely disseminated throughout the ore and not distinguishable except in the gouge layers. The appearance of the ore gave no clue to its tenor and determination of what was ore depended on assays. Sooty argentite also occurred in the ore, and the molybdenum-bearing minerals molybdenite and powellite occurred locally. Average grade of the ore in the Tonopah Divide mine was about 25 ounces per ton in silver and about $2.50 in gold. The ore occurred in a shoot about 400 feet long and 21 feet wide that pitched southward at a steep angle (Knopf, 1921, p. 167).

The age of mineralization in the Divide district is evidently younger than at Tonopah where the veins are restricted to the rocks beneath the Fraction Breccia. Whether the ore-bearing Mizpah Trachyte or other Tertiary units present at Tonopah extend beneath the Fraction Breccia in the Divide district is not known. If they are, there would seem to be the possibility of mineralization as at Tonopah.

Dyer District

The Dyer district consists of prospects and a few small mines and is in the westernmost part of the Silver Peak Range about 4 miles east-northeast of Dyer. The deposits (Spurr, 1906b, p. 84–85; Lincoln, 1923, p. 66) consist of black copper-silver sulfide, in places oxidized to copper carbonate, iron oxide, and silver chloride occurring in quartz veins in crushed and decomposed limestone and shaly limestone of the Poleta Formation of Early Cambrian Age. Some lead-silver ore also occurs. The deposits lie a short distance south of a small intrusive mass of granitic rock. The total recorded production of the district is only $12,817, and actual production probably was not large.

Fish Lake Marsh District

Fish Lake Marsh is in the west-central part of the county, west of the Silver Peak Range. Some borax has been produced from this area (see p. 61).

Fish Lake Valley (White Mountain) District

The Fish Lake Valley district, also called the White Mountain district, is at the north end of the White Mountains southeast of the Buena Vista district. Quicksilver apparently is the only commodity produced, although antimony occurs with the mercury in two of the mines (Lawrence, 1963, p. 64 and 66).

Individual mines and occurrences of mercury in the district have been described by Bailey and Phoenix (1944, p. 66–76). Much of the following summary description is taken from them and for additional information the reader is referred to their work.

The B & B mine is on the northern boundary of sec. 1, T. 1 S., R. 33 E. The property, discovered in 1927, is on top of a ridge at an elevation of about 7,700 feet. In 1960, when it was operated by the Kollsman Mineral and Chemical Corp. (P. M. Gardner, manager), daily production was about 200 tons of ore carrying 2 to 3 pounds of mercury per ton. Mining is by open-pit methods although it was earlier developed by underground workings. Total production is not known, but Bailey and Phoenix (1944, p. 69) list it at 2,659 flasks, and Lawrence and Wilson (1962) show it to be between 1,000 and 10,000 flasks.

The deposit is of the opalite type, and the replaced host rock is a fairly coarse air-fall tuff. The opalite is distinctly but irregularly banded with silicified layers generally ranging from 1 to 5 inches thick separated by thinner layers of soft chalky material and abundant open spaces. Cinnabar is rather erratically distributed through the siliceous layers. The best ore is said to have averaged over 20 pounds to the ton.

The base of the opalite blanket is in general parallel to bedding in the tuff but locally cuts sharply across the beds for several feet. No feeder channel for the mineralizing solutions was recognized beneath the opalite blanket but a northeast-trending fault that dips steeply northwest and has the opalized tuff in its hanging wall is believed by Bailey and Phoenix (1944, p. 69) to have possible genetic significance.

The Container mine in sec. 13, T. 1 N., R. 33 E., is in silicified rocks of the Palmetto Formation and is therefore a metamorphic-type deposit according to Bailey and Phoenix (1944, p. 70). The mine had a recorded production of 65 flasks to the end of 1942. Cinnabar occurs with some quartz and barite as small crystalline veinlets and as painty coatings in brecciated zones in the silicified rocks. It seems to be concentrated along or near faults, but well-defined control for ore deposition is lacking.

The F & L mine in sec. 36, T. 1 N., R. 33 E., is an opalite type of deposit similar to the B & B. There are two small opalite bodies, one measuring 60 by 20 feet and the other 80 by 100 feet (Bailey and Phoenix, 1944, p. 71). Cinnabar is disseminated in the most opalized rock but because nearly all the opalite is very blocky no real continuity for the ore could be demonstrated. According to Lawrence and Wilson (1962), the F & L mine has produced between one and ten flasks.

The Lucky (Red Cloud) property in sec. 2, T. 1 S., R. 33 E., is also a volcanic-type deposit, according to the classification of Bailey and Phoenix (1944, p. 72). The rocks are flat-lying agglomerate and tuff. Cinnabar with chalcedony is in a narrow veinlet trending N. 5° E., and dipping 65° E. The property has no recorded production.

The Red Rock mine, in sec. 18, T. 1 S., R. 34 E., is a metamorphic-type of deposit in phyllite and marble of the Palmetto Formation. Three parallel zones of gouge and altered rock striking N. 85° W. and dipping 45° S. are cut off by a fault that strikes N. 60° E. and dips 75° S. (Bailey and Phoenix, 1944, p. 73). The intersection of the fault and zones of gouge forms an inverted trough beneath which most of the mined ore was concentrated. Cinnabar is associated with quartz, barite, stibnite, stibiconite, limonite, and clays. The cinnabar occurs as crystalline seams filling cracks in the broken zone in the siliceous rock, and as coatings of "paint" on angular fragments of the same rock. High-grade lenses containing crystalline cinnabar occur locally within the fault zone. Up to the end of 1943, the Red Rock mine had produced 1,734 flasks of mercury, but it has been worked from time to time since then.

The Red Rose property, in sec. 35, T. 1 N., R. 33 E., is an opalite-type deposit along a northeast-trending fault in rhyolitic flows and tuffs. Cinnabar occurs as painty films and encrustations in the clay gouge along the fault and as scant disseminations in the silicified rhyolite along its footwall. Up to the end of 1942, the Red Rose property had produced one flask of mercury.

The Riek property, in sec. 11, T. 1 S., R. 35 E., is a sulfurous-type deposit in flat-lying rhyolitic or quartz latitic tuff. The associated minerals include chalcedony, sulfur, gypsum, and cinnabar (Bailey and Phoenix, 1944, p. 77). Cinnabar is disseminated in small amounts in the tuff and fills tiny seams and fractures in the sulfur. The latter mineral occurs as small blebs, irregular stringers, and blankets filling open spaces and fractures in the tuff. The property has no recorded production.

Other mercury prospects in the Fish Lake Valley district include the Buckskin, Sundown, Crimson Crown, and McNutt. These are all of the opalite or volcanic type. The O.K. mine (Bailey and Phoenix, 1944, p. 72; Lawrence and Wilson, 1962) and the Wild Rose mine (Bailey and Phoenix, 1944, p. 75) occur in the Fish Lake Valley district but are in Mineral County, Nev., if the county line is located properly on plate 1.

Gilbert (Desert) District

The Gilbert district, also called Desert district, is in the Monte Cristo Range in the northern part of the county. Original discoveries were in the 1800's, but discovery of high-grade ore in 1924 led to a short-lived boom. Total production has been small, and that which has been recorded is only 4,465 tons worth $104,960. The ore deposits apparently are related to two separate events (Ferguson, 1928): (1) intrusion of Mesozoic granitic rock, and (2) Tertiary volcanic activity. Deposits of the first type are represented by the Carrie mine (pl. 2), which contains silver-lead ore in quartz veins cutting limestone of the Palmetto Formation (Ordovician) within a mile of a small quartz monzonite intrusive. The second type includes most of the other named mines in the district (pl. 2). Most of these properties are gold-bearing quartz veins in Tertiary lavas and in the Ordovician Palmetto Formation, mostly near masses of intrusive rhyolite. Free gold is the principal valuable mineral, except at the Mammoth prospect where cerargyrite, ruby silver, and argentite are the principal ore minerals.

Mercury was discovered at the Castle Rock mine in the southern part of the district in 1928, and one flask of mercury was produced (Bailey and Phoenix, 1944, p. 75–76). The property was originally located for gold. The deposit is of the volcanic type and is in the Gilbert Andesite. Tuffs and breccias are locally silicified and brecciated. A chalcedony-cemented breccia vein ranges in thickness from 1 inch to a foot, and cinnabar occurs in fractures that cut the chalcedony. Associated minerals include jarosite, clays, and some pyrite. Cinnabar also fills fractures and open spaces in silicified andesite.

Goldfield District

More than 75 percent of the recorded mineral production of Esmeralda County has come from the Goldfield district (pl. 2), and at least 98 percent of the Goldfield production was from a belt less than a mile long and a few hundred feet wide. Allowing for the large amount of high grading by miners, total production may be as much as $100 million, but recorded production is $89,774,317 (table 7). The main period of activity was between 1904 and 1915.

The geology of the district has been described comprehensively by Ransome (1909a), and only a brief description will be given here. The principal rocks are Miocene volcanic rocks that overlie a basement of Ordovician shale and chert (Palmetto Formation) and Mesozoic granitic rock. The principal host rocks in which ore shoots occur are the Milltown Andesite and an overlying dacite. Both of these units give isotopic ages of about 21.5 million years. They are highly bleached and altered generally in a large eastward elongated elliptical belt that includes the principal productive part of the district. Elsewhere they have undergone only fairly weak propylitic alteration. The bleached rocks are argillized, alunitized, and silicified. Typically the most silicified and alunitized rock forms more or less linear ledges enclosed in soft argillized rock. The individual ledges range from a few feet to hundreds and locally to thousands of feet in length and from a few feet to many tens of feet wide. They occur mainly within and parallel to the margins of an eastward elongate elliptical area which measures about 5 to 7 miles long east-west and 3 to 4 miles north-south. It can be demonstrated that the major faulting in the district occurred prior to alteration and mineralization, and it is apparent that the ledges, which dip mostly at angles steeper than 40°, reflect an elliptical fracture system, possibly the rim fracture zone of a caldera.

The principal mineralized belt is a quartz-alunite ledge system that trends generally about north and dips 30° to 40° E. but which in detail has many peculiar bends and irregularities. The dip generally flattens with increasing depth. Individual ore bodies contained in the ledge system were typically rather small, extremely irregular in shape, and often very high in grade. According to Locke (1912, p. 845) the ore bodies were much like plums in a pudding and only 6 percent of the aggregate lode areas revealed

TABLE 7. Production from Goldfield district 1903–1960.

[Data from files of Nevada Bureau of Mines and Geology
and from U.S. Bureau of Mines Minerals Yearbooks, 1932–57]

Year	*Tons*	*Gold (ounces)*	*Silver (ounces)*	*Copper (pounds)*	*Lead (pounds)*	*Total value*
1903	....	3,419	287	....	....	$70,825
1904	8,000	113,293	19,954	....	....	2,353,353
1905	....	91,088	8,589	....	....	1,888,139
1906	59,628	339,890	15,648	....	....	7,036,638
1907	101,136	406,756	71,710	....	....	8,455,725
1908	88,152	236,082	30,823	1,606	....	4,896,799
1909	297,199	453,915	33,164	52,015	....	9,407,268
1910	339,219	538,760	117,598	107,282	....	11,214,278
1911	390,431	497,637	126,406	72,998	....	10,363,195
1912	362,777	301,848	125,736	579,539	3,581	6,412,859
1913	364,785	242,815	153,984	1,257,319	16,063	5,308,017
1914	367,166	227,612	129,830	1,069,021	4,018	4,919,302
1915	418,935	212,337	165,306	1,679,423	....	4,767,094
1916	383,456	128,250	129,781	1,317,400	2,418	3,060,801
1917	339,488	91,917	78,184	728,255	....	2,163,320
1918	264,237	58,658	90,560	548,847	....	1,438,697
1919	16,435	35,810	39,912	125,418	1,460	808,373
1920	6,571	7,536	6,081	13,440	....	164,890
1921	1,903	7,101	1,761	3,689	....	149,019
1922	5,619	12,773	5,755	....	....	270,065
1923	3,137	4,471	3,613	2,263	5,950	96,456
1924	7,352	4,336	3,982	17,901	....	....
1925	2,773	5,053	2,369	4,156	....	106,689
1926	1,250	2,196	1,251	1,425	....	46,376
1927	136,000	7,058	5,080	5,980	....	149,560
1928	1,355+	13,514	4,553	....	....	....
1929	279,513	12,768	5,946	10,805	....	269,018
1930	277,493	14,403	10,542	8,939	....	302,953
1931	274,586	12,920	6,359	10,537	....	269,874
1932	282,534	17,509	9,282	5,475	....	364,896
1933	232,693	7,779	3,017	2,175	....	162,009
1934	361,766	8,530	5,376	9,580	170	302,379
1935	349,212	7,070	3,449	7,066	84	250,535
1936	330,108	19,521	5,267	8,512	....	688,094
1937	342,815	16,521	8,226	2,700	4,000	585,161
1938	348,519	9,292	5,339	3,100	5,400	329,224
1939	380,461	8,130	4,210	4,000	....	287,824
1940	307,098	5,818	6,830	4,100	....	208,950
1941	3,019	3,288	1,807	2,000	400	116,624
1942	2,736	1,736	944	1,000	200	61,565
1943	143	122	284	1,700	3,600	4,963
1944	41	49	69	....	400	1,796
1945	95	35	287	....	2,000	1,601
1946	221	384	635	....	2,000	14,171
1947	69	57	458	....	....	2,409
1948	no production*					
1949				....	....	....
1950–1954	no production*					
1955	28	72	14	....	....	2,533
1956–1960	no production					
Totals	7,740,154	4,190,133	1,450,258	7,669,666	51,744	$89,774,317

*Production data (Newmont) withheld for 1948, 1949, 1950, and 1951.

in all the levels of the Goldfield Consolidated was occupied by ore. However, in certain areas there was more or less an alinement of ore bodies downdip so that their distribution was not completely haphazard. Nevertheless, prediction of the location and (or) grade of ore bodies was virtually impossible. The shape of some individual ore bodies was roughly equidimensional, whereas others were lenticular, still others platelike or tabular, and some were even spindle-shaped. Feeders for ore bodies were difficult to find and follow, but apparently in some places they led to the discovery of ore bodies. Very little ore was found as deep as 1,000 feet.

The gold was almost entirely in the form of very fine-grained native gold. Famatinite, bismuthinite, and pyrite were closely associated with it in the unoxidized ore which generally extended to within 150 feet of the surface. The gold/silver ratio was about 3 to 1. That the ore mineralization is younger than the alunitization and silicification is shown by its occurrence along fractures within the altered rock.

The Goldfield district in the broad sense also includes two other productive areas. One, the Sandstorm, was discovered a short while before the main district and is about a mile north of it. In the Sandstorm area ore shoots containing native gold were localized at the intersections of fractures in rhyolitic rock. Production was probably about $1.5 million. The other productive area was Diamondfield, which achieved some stature as a mining district and is described separately.

Good Hope (White Wolf) District

The Good Hope district, which is sometimes called the White Wolf district, lies in the southwestern part of the Silver Peak Mountains about 7 miles south of Piper Peak. Only a small production is recorded (table 6). According to H. W. Turner (*in* Spurr, 1906b, p. 85), the ore at the Good Hope mine (pl. 2) occurs in quartz along the contact of slate and quartzite. The quartz contains some galena, is copper stained, and was apparently worked for silver. Most of the mines or prospects in the district are in the Poleta Formation and occur in a northwest-trending belt of metasedimentary rocks lying between granitic intrusions.

Hornsilver (Lime Point, Gold Point) District

The Hornsilver district, also called the Lime Point or Gold Point district, is located in the southeast part of the county on Slate Ridge. Main production (Ransome, 1909b; Turner, 1922) is within a few miles southwest of Gold Point and is in a series of approximately parallel veins trending N. 55°–60° W., dipping steeply, and cutting across the bedding of the Precambrian Wyman Formation. The country rock is shale containing some limestone layers, although the wallrock is generally shale. The veins have been traced for distances up to 3,000 to 4,000 feet and are parallel to some fine-grained and rather obscurely exposed diorite dikes. The mines are within a few miles of a northeastward-extending finger of granitic rocks of the Sylvania pluton. The veins are mostly crushed quartz containing predominantly silver in the upper portion and gold in the lower portion. The silver is found as cerargyrite and sparingly as bromyrite, and the gold is native. Some galena and cerussite also occur. The recorded production is $736,609 (table 6), although actual production appears to have been near $1 million (Turner, 1922). One of the mines was worked in the early 1960's but was closed down in 1962.

Klondyke (Southern Klondyke) District

The Klondyke district, also called the Southern Klondyke district, is about 10 miles south of Tonopah near the eastern border of the county. The deposits have been described by Ball (1906, p. 58; 1907, p. 81–82) and Spurr (1903, p. 86–87; 1906c). Most of the deposits in the district occur in limestone of the Emigrant Formation (Middle and Upper Cambrian), which is cut by northwest-trending rhyolite dikes and intruded by irregular rhyolite bodies and one small granitic mass. A small iron prospect also occurs (see p. 57). According to Ball, the deposits are of three types, (1) quartz veins which are parallel to the bedding in the limestone and which carry predominantly silver values, (2) veins along the contact of the sedimentary rocks and rhyolite dikes with values predominantly gold, and (3) thin veins of quartz carrying silver-bearing galena and cerussite in granite along joint fractures parallel to the bedding of the surrounding rocks. Recorded production from the district has been relatively small, amounting to only 2,758 tons worth $67,352 (table 6).

Lida (Alida, Tule Canyon) District

The Lida district, which is also called the Alida or Tule Canyon district, is in the south-central part of the county and extends from a few miles north and east of the town of Lida to 8 to 10 miles south and west. The ore is mostly hornsilver or silver-bearing galena, although gold and copper occur in varying amounts (Ball, 1906, p. 61–62; 1907, p. 64–65; Root, 1909). The deposits occur in quartz or calcite veins mostly in limestone. The Deep Spring, Poleta, and Harkless Formations appear to be the main host rocks. Deposits in the southern part of the district occur in or in close proximity to granitic rocks of the Sylvania pluton. Recorded production from the Lida district is 5,573 tons worth $326,391.

Lone Mountain (West Divide, Weepah) District

The Lone Mountain district, which is also called the West Divide or Weepah district, covers a large area southwest of Tonopah in the north-central part of the county, generally near the Lone Mountain and Weepah plutons. The ore deposits occur in metamorphosed Precambrian and Cambrian sedimentary rocks, mostly limestone. The General Thomas mine (Ball, 1907), which is in the southeastern part of the district (pl. 2), is in limestone and shale, apparently of the Mule Spring Limestone (Lower Cambrian), or at the contact of the limestone and injected sheets of diorite porphyry. It is primarily a silver-lead mine containing some copper. The Alpine mine (Spurr, 1906b, p. 81–83) was not located during the course of the mapping but is on the westernmost part of Lone Mountain, apparently in the Reed Dolomite (Precambrian), within a mile of the Lone Mountain pluton. The ore is irregular replacement bodies of silver-bearing galena and small quartz seams containing galena; production has been at least $200,000. The Weepah mine (Oxnam, 1936) also has produced a sizable amount of ore, although the exact amount is not known. It is in the Wyman Formation (Precambrian) within a mile of granitic rocks of the Weepah pluton. The main values are in gold which occurs in a free state in a silicified gangue composed of quartz and altered country rock. The mine was discovered in 1904 and originally worked underground, but in 1935 a small open-pit operation was started (Oxnam, 1936). Until December 1, 1935, about 62,000 cubic yards of waste had been removed and 4,600 cubic yards of ore produced. Other mines in the district (Spurr, 1906b, p. 75–81), consist mostly of silver-bearing quartz veins in crushed zones parallel to the stratification of carbonate strata and mineralized zones near the contact of schist and marble intruded by diorite sills. The Gold Eagle mine (pl. 2) was worked in the early 1960's but was inactive in 1967. The ore contains zinc, lead, copper, and silver and occurs as a replacement of thin limestone layers in and adjacent to well-defined faults (H. K. Stager, written communication, 1960). The host rock is the Mule Spring Limestone (Lower Cambrian). Total recorded production from the district is 248,991 tons worth over $1,382,693.

Montezuma District

The Montezuma district is about 6 miles west of Goldfield and is predominantly a silver-lead district, although copper, gold, and bismuth occur in small amounts in some of the mines (Ball, 1906, p. 58–59; 1907, p. 63–64; Stretch, 1904; Lincoln, 1923, p. 78–79). The ore bodies consist of veins in limestone and shale and replacements in limestone and are predominantly in the Poleta Formation (Lower Cambrian), and, to a lesser extent, in the Reed Dolomite (Precambrian), Deep Spring Formation (Precambrian), Campito Formation (Precambrian and Lower Cambrian), and perhaps the Harkless Formation (Lower Cambrian). The gangue is chiefly quartz. According to Lincoln (1923, p. 79), the ore minerals at the surface are cerussite, native copper, malachite, azurite, manganese dioxide, and limonite; in depth these minerals give place to galena, chalcocite, and pyrite. He says further the principal values are in silver which is in the form of chlorides at the surface and of argentite in depth. Chlorobromides of silver have also been reported (Ball, 1907, p. 62). The district is cut by a few dikes, both of felsic and mafic types, but these appear to have no relationship to the ore bodies. A small granitic intrusion occurs directly north of the district, but many of the deposits are as much as 5 miles away. Total recorded production is 2,461 tons worth $223,663 (table 6), although total production is thought to have been about $500,000 (Stretch, 1904, p. 6).

A mercury prospect (the Montezuma prospect) occurs in the southern part of the district in sec. 17, T. 3 S., R. 41 E. (Bailey and Phoenix, 1944, p. 76–77). The deposit is of the opalite type in silicic Tertiary air-fall tuff slightly faulted against the Deep Spring Formation. The faulted contact strikes N. 60° W. and dips 30° SW. locally nearly paralleling the dip of the tuff which is extensively silicified to form a rib of opalite. The rib is 450 feet long by 30 feet wide at the surface. Cinnabar is disseminated in the unsilicified tuff beds and in the opalite near the faulted contact with limestone of the Deep Spring Formation. No production is recorded.

Palmetto District

The Palmetto district lies in and around the Palmetto Mountains in the south-central part of the county. The Windypah district is considered to be a part of the Palmetto district by some geologists, although it is described separately in this report. The production figures for the Palmetto district, however, also include those for the Windypah district.

The deposits are largely of silver, gold, and lead and occur in veins in the Palmetto pluton or in flanking lower Paleozoic strata. Most of the veins trend west or north-northwest generally parallel to the long direction of the Palmetto pluton. The host rock of the McNamara mine (pl. 2) is apparently limestone of the Emigrant Formation (Middle and Upper Cambrian), and the ore is in a vein along the undersurface of an alaskite dike (Spurr, 1906b, p. 93–94). Several mines occur in a 4-mile-long west- to northwest-trending zone of veins called the Paymaster zone by Spurr (1906b, p. 95–96), which cut entirely across the Palmetto pluton. Some of the mines and prospects in this zone are in granitic rocks, and some are in the Palmetto Formation (Ordovician), both to the north and south of the pluton. The largest mine in the district is apparently the Palmetto mine in the Palmetto Formation south of the pluton. The total recorded production of the district (including also production from the Windypah district) is 319 tons worth $14,686, but this figure is probably much too low as the Palmetto mine alone is thought to have produced $6,500,000 in silver (Lincoln, 1923, p. 80).

Railroad Springs District

Not much is known about the Railroad Springs district. It lies northeast of the Palmetto Mountains and apparently includes deposits in the area near the Big 3 mine shown on plate 2. It is sometimes considered a part of the Lida district that adjoins it on the south. According to Lincoln (1923, p. 80–81), the district includes gold-, silver-, and copper-bearing veins in limestone and shale that have been intruded by diorite dikes. At least some of these deposits are probably in the Poleta Formation of Early Cambrian Age. The recorded production from the district is only 56 tons worth $4,568 (table 6).

Rock Hill District

The name Rock Hill district is sometimes applied to an area in the northern part of the county about 8 miles north of Coaldale. This area includes a placer deposit from which scheelite has been recovered (see p. 59) and the Boak mine that has produced some iron (see p. 57).

Silver Peak Marsh (Clayton Valley) District

Silver Peak Marsh, in the central part of the county, contains one of the world's principal sources of lithium (see p. 58). Salt has been mined from the marsh for local use and potash and borate minerals occur in noncommercial amounts (Lincoln, 1923, p. 83).

Silver Peak (Red Mountain, Mineral Ridge, Argentite) District

The Silver Peak district (pl. 2) has also been called the Red Mountain district and the Mineral Ridge district. The westernmost part near the center of the Silver Peak Range is sometimes referred to as the Argentite district (Lincoln, 1923, p. 60). Preferably the district should be divided into a Red Mountain district and a Mineral Ridge district as the geology and mineral deposits in the two parts are markedly different. The deposits in the northern (Mineral Ridge) part are gold-bearing quartz veins and irregular quartz masses in the Precambrian Wyman Formation, whereas the deposits in the southern (Red Mountain) part are silver-bearing veins in volcanic rocks of mid-Pliocene Age. Total recorded production of the Silver Peak district is $16,312,849, making it second to Goldfield in total dollar value.

The Mineral Ridge area was worked in the 1860's and 1870's but the main period of activity was 1933 to 1942. The principal mines are shown on plate 2.

According to Spurr (1906b, p. 38), the ore in Mineral Ridge occurs in quartz lenses of various dimensions as seen in both the horizontal and vertical plane. Judging from Spurr's sketches and from observations during the present study, the lenses generally dip at low angles. Along the ore zone the lenses typically overlap and disappear by wedging out and in places by forking or splitting into several forks. Thus a series of quartz stringers in the Wyman Formation may unite laterally or vertically and widen to 3 or 4 feet of solid quartz. The more highly auriferous veins are concentrated in certain zones and lenses. The main stope in the Drinkwater mine workings is said by Spurr (1906b, p. 38) to be an example of this type of occurrence. In addition to the low dipping, irregular lenticular masses of quartz described by Spurr (1906a, b), the abundance of pits and trenches along a series of quartz veins that strike north and dip nearly vertical suggest that a fair amount of gold was produced from steep tabular veins, possibly in later years.

Spurr (1906b, p. 37) states that the ore is a typical white crystalline quartz which under the microscope is seen to be crowded with liquid inclusions. Silver, nearly always present, has only an average value of 1 percent compared to gold. The gold is commonly finely disseminated free gold, but it is also contained in pyrite and galena which together form about 1 percent of the ore.

The southern (Red Mountain) part of the Silver Peak district was born in 1907 with the discovery of the Nivloc mine. This mine was operated chiefly during the period 1937 to 1943 and produced $2 to $3 million worth of ore averaging 0.05 ounces of gold and 11.0 ounces of silver per ton. The Mohawk mine, about 4 miles northwest of the Nivloc, was discovered around 1920 and had its main productive period in the late 1950's. Its ore averaged 20 to 25 ounces of silver per ton. A third deposit, the Sixteen-to-One, lies between the Nivloc and Mohawk and was discovered in the 1920's. It has no recorded production.

The Nivloc, Sixteen-to-One, and Mohawk mines, as well as several smaller deposits, lie in a mineralized zone that trends northwest. However, the veins themselves strike northeast. They are in Tertiary volcanic host rocks the youngest of which has an isotopic age of about 5.9 million years. How much younger the veins are than the host rock is not known, but it is presumed that they are genetically related to volcanism and therefore not much younger.

The veins throughout the southern (Red Mountain) part of the Silver Peak district are very similar. Massive and banded quartz and calcite, barite, siderite, and locally manganosiderite are the gangue minerals. Fine-grained argentite appears to be the principal ore mineral. Traces of gold and small amounts of lead and zinc are other metallic components. The veins are typically banded and all indications are that they are formed by fracture filling in the epithermal zone. Outcrops of all veins in the southern part of the district are leached of most of their silver values, and much of the ore mined was presumably secondarily enriched.

Sylvania (Green Mountain) District

The Sylvania district, also called the Green Mountain district, has a recorded production of only 347 tons, worth $19,881. The district lies near the western boundary of the southern third of the county. The deposits mostly occur in a mile-wide northwest-trending belt of the Precambrian Wyman Formation lying largely within quartz monzonite of the Sylvania pluton. Some deposits also occur within the pluton. The deposits are mostly silver and lead (Lincoln, 1923, p. 83), although some gold occurs, and tungsten was produced in small quantities apparently in 1943 and in the early 1950's (Schilling, 1963a). According to Lincoln (1923, p. 83), most of the silver-lead deposits are veins in limestone and contain argentiferous galena and lead carbonates. Talc deposits are numerous in the district and most occur along a thrust fault with porphyritic quartz monzonite in the upper plate and the Precambrian Reed Dolomite and Wyman Formation in the lower plate (see description under "Talc and Soapstone").

Tokop (Gold Mountain, Oriental Wash, Bonnie Claire) District

The Tokop district, also called the Gold Mountain, Oriental Wash, or Bonnie Claire, is the southernmost district in the county and includes deposits on the south flank of Gold Mountain, near Tokop, about 3 miles northeast of Gold Mountain, and on the east side of Death Valley about 10 miles west southwest of Gold Mountain. The latter locality is sometimes called the Oriental Wash district. The deposits (Ball, 1906, p. 62–65; 1907, p. 187–191; Ransome, 1907, p. 80–83) are primarily gold, although some silver, copper, and lead are present, and occur in quartz veins in granitic rocks of the Sylvania pluton or in flanking metamorphosed shale and limestone of the

Wyman Formation (Precambrian). Tungsten also occurs on the south side of Gold Mountain (see p. 59). Recorded production from the district is 239 tons worth $3,985 (table 6).

Tonopah District

The Tonopah district lies in and around the town of Tonopah, partly in Esmeralda County but mostly in Nye County. The main deposit, from which most of the production has come, extends from Tonopah westward for about 2 miles and includes about three-quarters of a mile in Esmeralda County. Silver is the main metal, and total production from the district is about $100 million, of which less than $3 million is from Esmeralda County. The ore bodies are replacement veins in Tertiary volcanic rocks and occur along a recumbent curving fault that is convex upward and other faults that branch from it (Nolan, 1935). Ore shoots are restricted to a zone 600 to 1,000 feet thick that generally conforms in shape with a zone of quartz-adularia-sericite alteration (Nolan, 1935, p. 12, 41–43).

Windypah (Fesler) District

The Windypah, or Fesler, district is in the southernmost part of the Silver Peak Mountains, about 10 miles north-northwest of the Palmetto Mountains. This district is sometimes considered a part of the Palmetto district but is described separately here because most of the mines lie at least 6 miles from those in the latter district. Production from the districts has not been recorded separately, however, and table 6 shows the combined total for the two districts.

Mines and prospects in the district occur partly in granitic rocks of the Palmetto and Palmetto Wash plutons and partly in flanking lower Paleozoic hornfels, slate, and marble. Four classes of veins have been described by Spurr (1906b, p. 85–92), the main source of information on the district. The first type consists of lenses and irregular bodies of quartz within alaskite. The quartz contains pyrite and in some places has good values in gold. The second type is along shear zones in granitic rock and consists of gold-bearing quartz. The third type is in limestone and slate at or near the contact with granitic rocks or with alaskite dikes. These veins occur in the Palmetto Formation (Ordovician) north of the Palmetto pluton and in the Poleta and Harkless Formations (Lower Cambrian), as well as the Palmetto Formation in a narrow northwest-trending septa between the Palmetto and Palmetto Wash plutons. The ore consists of a rich black auriferous sulfide of silver and copper; silver is the main economic mineral. The fourth type of vein is intermediate between the second and third types and consists of veins along shear zones in granite. The main values are in gold, but the veins contain some black silver minerals similar to those in the third type of veins. Most of the veins in the Windypah district trend west-northwest to north-northwest (Spurr, 1906b, p. 1).

REFERENCES

Albers, J. P., 1967, Belt of sigmoidal bending and right-lateral faulting in the western Great Basin: Geol. Soc. America Bull., v. 78, no. 2, p. 143–155.

Albers, J. P., and Stewart, J. H., 1962, Precambrian(?) and Cambrian stratigraphy in Esmeralda County, Nevada, *in* Geological Survey research, 1962: U.S. Geol. Survey Prof. Paper 450–D, p. D24–D27.

———, 1965, Preliminary geologic map of Esmeralda County, Nevada: U.S. Geol. Survey Map MF–298.

Bailey, E. H., and Phoenix, D. A., 1944, Quicksilver deposits in Nevada: Nevada Univ. Bull., v. 38, no. 5; Geol. and Min. Ser. 41.

Bailly, P. A., 1951, Geology of the southeastern part of Mineral Ridge, Esmeralda County, Nevada: Ph.D. thesis, Stanford Univ., Stanford, Calif.

Bailly, P. A., and Compton, R. R., 1955, Precambrian plutonism at Mineral Ridge, Esmeralda County, Nevada [abs.]: Geol. Soc. America Bull., v. 66, no. 12, pt. 2, p. 1528.

Ball, S. H., 1906, Notes on ore deposits of southwestern Nevada and eastern California: U.S. Geol. Survey Bull. 285, p. 53–73.

———, 1907, A geologic reconnaissance in southwestern Nevada and eastern California: U.S. Geol. Survey Bull. 308.

Benson, W. T., 1950, Investigation of Black Rock manganese deposits, Esmeralda County, Nevada: U.S. Bur. Mines Rept. Inv. 4717.

Billingsley, Paul, and Locke, Augustus, 1939, Structure of ore districts in the continental framework: New York, Am. Inst. Mining Metall. Engineers.

Branner, G. C., 1959, Sulphur in California and Nevada: U.S. Bur. Mines Inf. Circ. 7898.

Brew, D. A., 1961, Lithologic character of the Diamond Peak Formation (Mississippian) at the type locality, Eureka and White Pine Counties, Nevada, *in* Geological Survey research, 1961: U.S. Geol. Survey Prof. Paper 424–C, p. C110–C112.

Bryson, R. P., 1937, Faulted fanglomerates at the mouth of Perry Aiken Creek, Northern Inyo Range, California-Nevada: M.S. thesis, California Inst. Technology, Pasadena, Calif.

Butler, A. P., Jr., Finch, W. I., and Twenhofel, W. S., compilers, 1962, Epigenetic uranium in the United States, exclusive of Alaska and Hawaii: U.S. Geol. Survey Mineral Inv. Resource Map MR–21.

Byers, F. M., Jr., Barnes, Harley, Poole, F. G., and Ross, R. J., Jr., 1961, Revised subdivision of Ordovician System at the Nevada Test Site and vicinity, *in* Geological Survey research, 1961: U.S. Geol. Survey Prof. Paper 424–C, p. C106–C110.

Chidester, A. H., Engel, A. E. J., and Wright, L. A., 1964, Talc resources of the United States: U.S. Geol. Survey Bull. 1167.

Cooper, John R., 1962, Bismuth in the United States, exclusive of Alaska and Hawaii: U.S. Geol. Survey Mineral Inv. Resource Map MR–22.

Cornwall, H. R., and Kleinhampl, F. J., 1961, Geology of the Bare Mountain quadrangle, Nevada: U.S. Geol. Quad. Map GQ–157.

Couch, B. F., and Carpenter, J. A., 1943, Nevada's metal and mineral production (1859–1940, inclusive): Nevada Univ. Bull., v. 37, no. 4; Geol. and Min. Ser. no. 38.

Davis, D. L., and Hetland, D. L., 1956, Uranium in clastic rocks of the Basin and Range province, *in* Page, L. R., and others, Contributions to the geology of uranium and thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations International Conference on peaceful uses of atomic energy, Geneva, Switzerland, 1955: U.S. Geol. Survey Prof. Paper 300, p. 351–359.

Dole, R. B., 1911, Exploration of salines in Silver Peak Marsh, Nevada: U.S. Geol. Survey Bull. 530, p. 330–345 [1913].

Dover, J. H., 1962, Geology of the northern Palmetto Mountains, Esmeralda County, Nevada: M.S. thesis, Washington Univ., Seattle, Wash.

Duncan, D. C., 1953, A uranium-bearing rhyolitic tuff deposit near Coaldale, Esmeralda County, Nevada: U.S. Geol. Survey Circ. 291.

Eakin, T. E., 1950, Preliminary report on ground water in Fish Lake Valley, Nevada and California: Nevada State Engineer's Office, Water Resources Bull. no. 11, p. 7–33.

Evernden, J. F., and James, G. T., 1964, Potassium-argon dates and the Tertiary floras of North America: Am. Jour. Sci., v. 262, no. 8, p. 945–974.

Evernden, J. F., Savage, D. E., Curtis, G. H., and James, G. T., 1964, Potassium-argon dates and the Cenozoic mammalian chronology of North America: Am. Jour. Sci., v. 262, no. 2, p. 145–198.

Ferguson, H. G., 1924, Geology and ore deposits of the Manhattan district, Nevada: U.S. Geol. Survey Bull. 723.

———, 1928, The Gilbert district, Nevada: U.S. Geol. Survey Bull. 795, p. 125–145.

Ferguson, H. G., and Muller, S. W., 1949, Structural geology of the Hawthorne and Tonopah quadrangles, Nevada: U.S. Geol. Survey Prof. Paper 216.

Ferguson, H. G., Muller, S. W., and Cathcart, S. H., 1953, Geology of the Coaldale quadrangle, Nevada: U.S. Geol. Survey Geol. Quad. Map GQ–23.

———, 1954, Geology of the Mina quadrangle, Nevada: U.S. Geol. Survey Geol. Quad. Map GQ–45.

Fiedler, W. M., 1937, Structure and stratigraphy of a section across the White Mountains, California: M.S. thesis, California Inst. Technology, Pasadena, Calif.

Foshag, W. F., 1934, Searlesite from Esmeralda County, Nevada: Am. Mineralogist, v. 19, no. 6, p. 268–274.

Fulton, J. A., and Smith, A. M., 1932, Nonmetallic minerals in Nevada: Nevada Univ. Bull., v. 26, no. 7.

Gale, H. S., 1912, Potash tests at Columbus Marsh, Nevada: U.S. Geol. Survey Bull. 540, p. 422–427 [1914].

Giannella, V. P., and Callaghan, Eugene, 1934, The earthquake of December 20, 1932, at Cedar Mountain, Nevada, and its bearing on the genesis of Basin Range structure: Jour. Geology, v. 42, no. 1, p. 1–22.

Hance, J. H., 1913, The Coaldale coal field, Esmeralda County, Nevada: U.S. Geol. Survey Bull. 531, p. 313–322.

Hewett, D. F., Callaghan, Eugene, Moore, B. N., Nolan, T. B., Rubey, W. W., and Schaller, W. T., 1936, Mineral resources of the region around Boulder Dam: U.S. Geol. Survey Bull. 871.

Hicks, W. B., 1915, The composition of muds from Columbus Marsh, Nevada: U.S. Geol. Survey Prof. Paper 95, p. 1–11.

Horton, R. C., 1961, An inventory of fluorspar occurrences in Nevada: Nevada Bur. Mines Rept. 1.

———, 1963, An inventory of barite occurrences in Nevada: Nevada Bur. Mines Rept. 4.

Horton, R. C., Bonham, H. F., Jr., and Longwill, W. D., compilers, 1962, Lead occurrences in Nevada by district: Nevada Bur. Mines Map 14.

Jackson, E. D., and Ross, D. C., 1956, A technique for modal analyses of medium- and coarse-grained (3–10 mm) rocks: Am. Mineralogist, v. 41, nos. 7–8, p. 648–651.

Johannsen, Albert, 1939, Introduction, textures, classifications, and glossary, v. 1, *of* A descriptive petrography of the igneous rocks, 2d ed.: Chicago, Ill., Univ. Chicago Press.

Knapp, M. A., 1897, The coal fields of Esmeralda County, Nevada: Mining and Sci. Press, v. 74, p. 133.

Knopf, Adolph, 1921, The Divide silver district, Nevada: U.S. Geol. Survey Bull. 715, p. 147–170.

———, 1922, The Candelaria silver district, Nevada: U.S. Geol. Survey Bull. 735, p. 1–22.

Lawrence, E. F., 1963, Antimony deposits of Nevada: Nevada Bur. Mines Bull. 61.

Lawrence, E. F., and Wilson, R. V., 1962, Mercury occurrences in Nevada: Nevada Bur. Mines Map 7.

Lincoln, F. C., 1923, Mining districts and mineral resources of Nevada: Reno, Nev. Newsletter Publishing Co.

Locke, Augustus, 1912, The ore deposits of Goldfield [Nevada]: Eng. Mining Jour., v. 94, no. 18, p. 797–802, 843–849.

Locke, Augustus, Billingley, P. R., and Mayo, E. B., 1940, Sierra Nevada tectonic patterns: Geol. Soc. America Bull., v. 51, no. 4, p. 513– 540.

McAllister, J. F., 1952, Rocks and structure of the Quartz Spring area, northern Panamint Range, California: California Div. Mines Spec. Rept. 25.

McKee, E. D., 1957, Primary structures in some Recent sediments [U.S. and Mexico]: Am. Assoc. Petroleum Geologists Bull., v. 41, no. 8, p. 1704–1747.

McKee, E. H., 1962, The stratigraphy and structure of a portion of the Magruder Mountain-Soldier Pass quadrangles, California-Nevada: Ph.D. thesis, California Univ., Berkeley, Calif.

———, 1968, Geology of the Magruder Mountain area, Nevada-California: U.S. Geol. Survey Bull. 1251–H, p. H1–H40.

McKee, E. H., and Moiola, R. J., 1962, Precambrian and Cambrian rocks at south-central Esmeralda County, Nevada: Am. Jour. Sci., v. 260, no. 7, p. 530–538.

McKee, E. H., and Nash, D. B., 1967, Potassium-argon ages of granitic rocks in the Inyo batholith, east-central California: Geol. Soc. America Bull., v. 78, no. 5, p. 669–679.

Morrissey, F. R., 1968, Turquoise deposits of Nevada: Nevada Bur. Mines Rept. 17.

Muller, S. W., and Ferguson, H. G., 1936, Triassic and Jurassic formations of west-central Nevada: Geol. Soc. America Bull., v. 47, no. 2, p. 241–251.

———, 1939, Mesozoic stratigraphy of the Hawthorne and Tonopah quadrangles, Nevada: Geol. Soc. America Bull., v. 50, no. 10, p. 1573–1624.

Murphy, J. B., 1964, Gems and gem materials, *in* Mineral and water resources of Nevada: Nevada Bur. Mines Bull. 65, p. 203–208.

Nelson, C. A., 1962, Lower Cambrian-Precambrian succession, White-Inyo Mountains, California: Geol. Soc. America Bull., v. 73, no. 1, p. 139–144.

———, 1963, Stratigraphic range of *Ogygopsis:* Jour. Paleontology, v. 37, no. 1, p. 244–248.

———, 1966a, Geologic map of the Waucoba Mountain quadrangle, Inyo County, California: U.S. Geol. Survey Geol. Quad. Map GQ–528.

———, 1966b, Geologic map of the Blanco Mountain quadrangle, Inyo and Mono Counties, California: U.S. Geol. Survey Geol. Quad. Map GQ–529.

Nielsen, R. L., 1965, Right-lateral strike-slip faulting in the Walker Lane, west-central Nevada: Geol. Soc. America Bull., v. 76, no. 11, p. 1301–1308.

Noble, D. C., Anderson, R. E., Ekren, E. B., and O'Connor, J. T., 1964, Thirsty Canyon tuff of Nye and Esmeralda Counties, Nevada, *in* Geological Survey research, 1963: U.S. Geol. Survey Prof. Paper 475–D, p. D24–D27.

Noble, D. C., Bath, G. D., Christiansen, R. L., and Orkild, P. P., 1968, Zonal relations and paleomagnetism of the Spearhead and Rocket Wash Members of the Thirsty Canyon Tuff, southern Nevada, *in* Geological Survey research, 1968: U.S. Geol. Survey Prof. Paper 600–C, p. C61–C65.

Nolan, T. B., 1935, The underground geology of the Tonopah mining district, Nevada: Nevada Univ. Bull., v. 29, no. 5

Nolan, T. B., Merriam, C. W., and Williams, J. S., 1956, The stratigraphic section in the vicinity of Eureka, Nevada: U.S. Geol. Survey Prof. Paper 276.

Olson, J. C., and Adams, J. W., compilers, 1962, Thorium and rare earths in the United States, exclusive of Alaska and Hawaii: U.S. Geol. Survey Mineral Inv. Resource Map MR–28.

Olson, J. C., and Hinrichs, E. N., 1960, Beryl-bearing pegmatites in the Ruby Mountains and other areas in Nevada and northwestern Arizona: U.S. Geol. Survey Bull. 1082–D, p. D135–D200.

Olson, R. H., 1964a, Clays, *in* Mineral and water resources of Nevada: Nevada Bur. Mines Bull. 65, p. 185–189.

———, 1964b, Silica, *in* Mineral and water resources of Nevada: Nevada Bur. Mines Bull. 65, p. 244–247.

Oxnam, T. H., 1936, Weepah gold: Eng. and Mining Jour., v. 137, no. 6, p. 300–303, 306.

Page, B. M., 1959, Geology of the Candelaria mining district, Mineral County, Nevada: Nevada Bur. Mines Bull. 56.

Palmer, A. R., 1964, An unusual Lower Cambrian trilobite fauna from Nevada: U.S. Geol. Survey Prof. Paper 483–F, p. F1–F13.

Pardee, J. T., and Jones, E. L., Jr., 1920, Deposits of manganese ore in Nevada: U.S. Geol. Survey Bull. 710, p. 209–248.

Phalen, W. C., 1919, Salt resources of the United States: U.S. Geol. Survey Bull. 669.

Poole, F. G., Houser, F. N., and Orkild, P. P., 1961, Eleana Formation of Nevada Test Site and vicinity, Nye County, Nevada, *in* Geological Survey research, 1961: U.S. Geol. Survey Prof. Paper 424–D, p. D104–D111.

Ransome, F. L., 1907, Preliminary account of Goldfield, Bullfrog, and other mining districts in southern Nevada, *with* Notes on the Manhattan district, by G. H. Garrey and W. H. Emmons: U.S. Geol. Survey Bull. 303.

———, 1909a, The geology and ore deposits of Goldfield, Nevada: U.S. Geol. Survey Prof. Paper 66.

———, 1909b, The Hornsilver district, Nevada: U.S. Geol. Survey Bull. 380, p. 41–43.

Reeves, R. G., Shawe, F. R., and Kral, V. E., 1958, Iron ore deposits of west-central Nevada, Pt. B *of* Iron ore deposits of Nevada: Nevada Bur. Mines Bull. 53, p. 33–78.

Roberts, R. J., Hotz, P. E., Gilluly, James, Ferguson, H. G., 1958, Paleozoic rocks of north-central Nevada: Am. Assoc. Petroleum Geologists Bull., v. 42, no. 12, p. 2813–2857.

Robinson, P. T., 1964, Cenozoic stratigraphy and structure of the central part of the Silver Peak Ranch, Esmeralda County, Nevada: Ph.D. thesis, California Univ., Berkeley, Calif.

———, 1968, Silver Peak volcanic center, Esmeralda County, Nevada [abs.]: Geol. Soc. America Spec. Paper 115, p. 349.

Robinson, P. T., McKee, E. H., and Moiola, R. J., 1968, Cenozoic volcanism and sedimentation, Silver Peak region, western Nevada and adjacent California, *in* Coats, R. R., Hay, R. L., and Anderson, C. A., eds., Studies in volcanology — a memoir in honor of Howel Williams: Geol. Soc. America Mem. 116, p. 577–611.

Root, W. A., 1909, The Lida mining district of Nevada: Mining World, v. 31, p. 123–125.

Ross, C. S., and Smith, R. L., 1961, Ash-flow tuffs — their origin, geologic relations and identification: U.S. Geol. Survey Prof. Paper 366.

Ross, D. C., 1961, Geology and mineral deposits of Mineral County, Nevada: Nevada Bur. Mines Bull. 58.

Ross, R. J., Jr., and Berry, W. B. N., 1963, Ordovician graptolites of the Basin Ranges in California, Nevada, Utah, and Idaho: U.S. Geol. Survey Bull. 1134.

Schilling, J. H., 1962a, Molybdenum occurrences in Nevada: Nevada Bur. Mines Map 8.

———, 1962b, An inventory of molybdenum occurrences in Nevada: Nevada Bur. Mines Rept. 2.

Schilling, J. H., 1963a, Tungsten mines in Nevada: Nevada Bur. Mines Map 18.

———, 1963b, Uranium occurrences in Nevada: Nevada Bur. Mines Map 19.

———, 1964a, Tungsten, *in* Mineral and water resources of Nevada: Nevada Bur. Mines Bull. 65, p. 155–161.

———, 1964b, Rhenium, *in* Mineral and water resources of Nevada: Nevada Bur. Mines Bull. 65, p. 133.

———, 1965, Isotopic age determinations of Nevada rocks: Nevada Bur. Mines Rept. 10.

Searls, Fred, Jr., 1948, A contribution to the published information on the geology and ore deposits of Goldfield, Nevada: Nevada Univ. Bull., v. 42, no. 5, Geol. and Min. Ser. no. 48.

Smith, W. C., 1964, Borates, *in* Mineral and water resources of Nevada: Nevada Bur. Mines Bull. 65, p. 180–184.

Spurr, J. E., 1903, Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: U.S. Geol. Survey Bull. 208.

———, 1904, Coal deposits between Silver Peak and Candelaria, Esmeralda County, Nevada, *in* Contributions to economic geology: U.S. Geol. Survey Bull. 225, p. 289–292.

———, 1905, Geology of the Tonopah mining district, Nevada: U.S. Geol. Survey Prof. Paper 42.

———, 1906a, Genetic relations of the western Nevada ores: Am. Inst. Mining Engineers Trans., v. 36, p. 372–402.

———, 1906b, Ore deposits of the Silver Peak quadrangle, Nevada: U.S. Geol. Survey Prof. Paper 55.

Spurr, J. E., 1906c, The Southern Klondyke district, Esmeralda County, Nevada — a study in metalliferous quartz veins of magmatic origin: Econ. Geology, v. 1, no. 4, p. 369–382.

Stewart, J. H., 1966, Correlation of Lower Cambrian and some Precambrian strata in the southern Great Basin, California and Nevada, *in* Geological Survey research, 1966: U.S. Geol. Survey Prof. Paper 550–C, p. C66–C72.

———, 1967, Possible large right-lateral displacement along fault and shear zones in the Death Valley-Las Vegas area, California and Nevada: Geol. Soc. America Bull., v. 78, no. 2, p. 131–142.

———, Stewart, J. H., Ross, D. C., Nelson, C. A., and Burchfiel, B. C., 1966, Last Chance thrust — a major fault in the eastern part of Inyo County, California, *in* Geological Survey research, 1966: U.S. Geol. Survey Prof. Paper 550–D, p. D23–D34.

Stock, Chester, and Bode, F. D., 1935, Occurrence of lower Oligocene mammal-bearing beds near Death Valley, California: Natl. Acad. Sci. Proc., v. 21, no. 10, p. 571–579.

Stretch, R. H., 1904, The Montezuma district, Nevada: Eng. and Mining Jour., v. 78, p. 5–6.

Thompson, T. H., and West, A. A., 1881, History of Nevada: Berkeley, Calif., Howell-North [1958].

Tolman, C. F., and Ambrose, J. W., 1934, The rich ores of Goldfield, Nevada: Econ. Geology, v. 29, no. 3, p. 255–279.

Turner, H. W., 1900, The Esmeralda formation, a fresh water lake deposit: U.S. Geol. Survey Ann. Rept. 21, pt. 2, p. 191–208.

———, 1902, A sketch of the historical geology of Esmeralda County, Nevada: Am. Geologist, v. 29, p. 261–272.

———, 1909, Contribution to the geology of the Silver Peak quadrangle, Nevada: Geol. Soc. America Bull., v. 20, p. 223–264.

Turner, J. K., 1922, The Hornsilver mining district: Mining and Sci. Press, v. 124, no. 3, p. 93–94.

U.S. Bureau of Mines, 1932–1965, Mineral Yearbooks.

Walcott, C. D., 1908, Cambrian sections of the Cordilleran area, *in* Cambrian geology and paleontology: Smithsonian Misc. Colln., v. 53, p. 167–230.

Whitney, J. D., 1866, [Remarks on the geology of the State of Nevada]: California Acad. Sci. Proc., 1st ser., v. 3, p. 266–270.

Wilson, H. D. B., 1944, Geochemical studies of the epithermal deposits at Goldfield, Nevada: Econ. Geology, v. 39, no. 1, p. 37–55.

Wilson, J. S., 1961, Cambrian paleontology and stratigraphy of the Miller Mountain area, Esmeralda County, Nevada: M.A. thesis, California Univ., Los Angeles, Calif.

Wood, H. B., 1956, Relations of the origin of host rocks to uranium deposits and ore production in western United States, *in* Page, L.P., and others, Contributions to the geology of uranium and thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations International Conference on peaceful uses of atomic energy, Geneva, Switzerland, 1955: U.S. Geol. Survey Prof. Paper 300, p. 533–541.

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1. QANA

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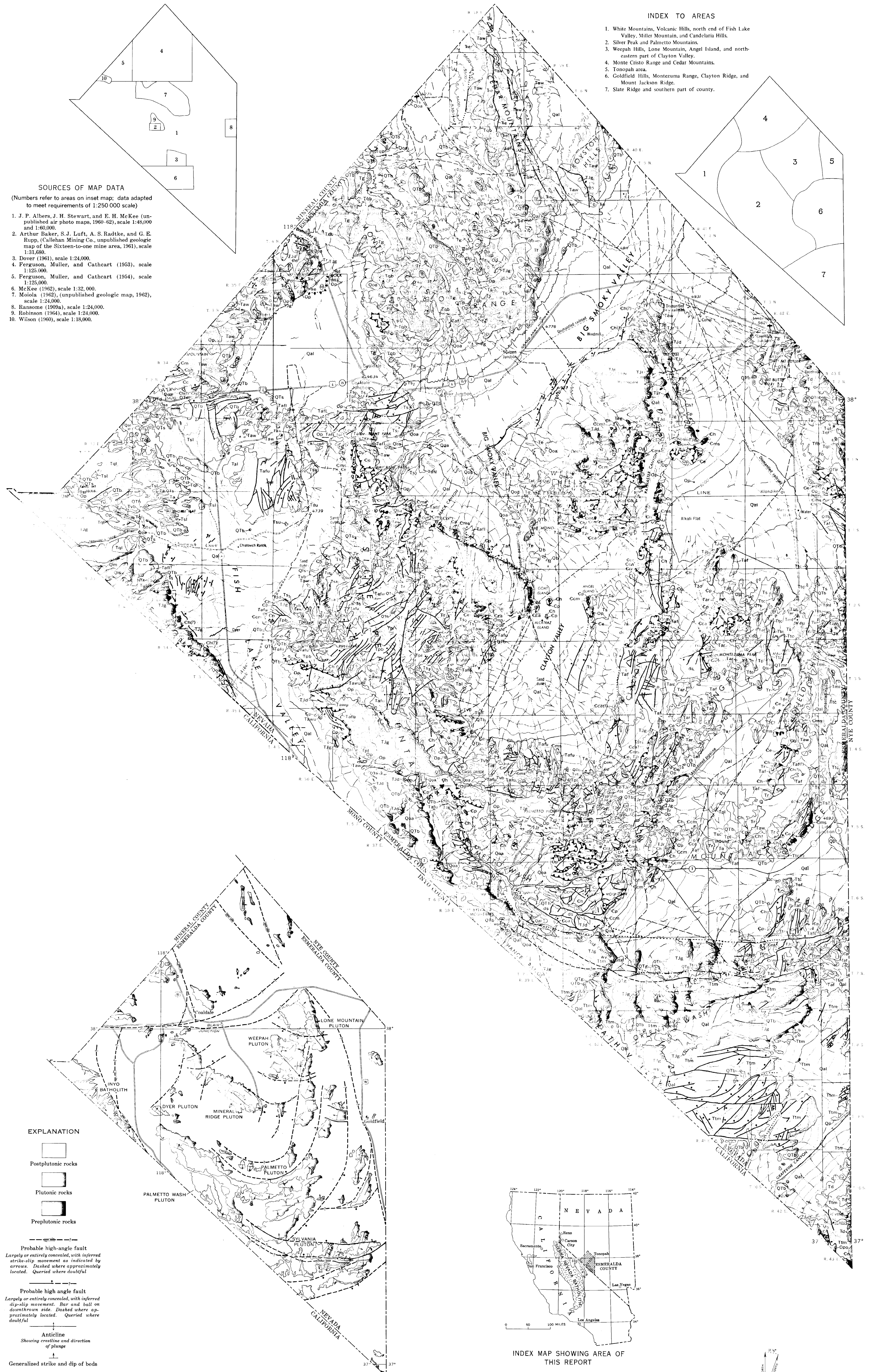

SOURCES OF MAP DATA

(Numbers refer to areas on inset map; data adapted to meet requirements of 1:250 000 scale)

1. J. P. Albers, J. H. Stewart, and E. H. McKee (unpublished air photo maps, 1960–62), scale 1:48,000 and 1:40,000.
2. Arthur Baker, S. J. Luft, A. S. Radtke, and G. E. Rupp, (Callahan Mining Co., unpublished geologic map of the Sixteen-to-one mine area, 1961), scale 1:31,680.
3. Dover (1961), scale 1:24,000.
4. Ferguson, Muller, and Cathcart (1953), scale 1:125,000.
5. Ferguson, Muller, and Cathcart (1954), scale 1:125,000.
6. McKee (1962), scale 1:32,000.
7. Moiola (1962), (unpublished geologic map, 1962), scale 1:24,000.
8. Ransome (1909a), scale 1:24,000.
9. Robinson (1964), scale 1:24,000.
10. Wilson (1960), scale 1:18,000.

INDEX TO AREAS

1. White Mountains, Volcanic Hills, north end of Fish Lake Valley, Miller Mountain, and Candelaria Hills.
2. Silver Peak and Palmetto Mountains.
3. Weepah Hills, Lone Mountain, Angel Island, and northeastern part of Clayton Valley.
4. Monte Cristo Range and Cedar Mountains.
5. Tonopah area.
6. Goldfield Hills, Montezuma Range, Clayton Ridge, and Mount Jackson Ridge.
7. Slate Ridge and southern part of county.

EXPLANATION

Postplutonic rocks

Plutonic rocks

Preplutonic rocks

Probable high-angle fault
Largely or entirely concealed, with inferred strike-slip movement as indicated by arrows. Dashed where approximately located. Queried where doubtful

Probable high angle fault
Largely or entirely concealed, with inferred dip-slip movement. Bar and ball on downthrown side. Dashed where approximately located. Queried where doubtful

Anticline
Showing crestline and direction of plunge

Generalized strike and dip of beds

MAP SHOWING LOCATION OF PLUTONS AND PRINCIPAL STRUCTURAL FEATURES IN PRE-TERTIARY ROCKS (EXCEPT SOME PLUTONS OF EARLY TERTIARY AGE), ESMERALDA COUNTY

INDEX MAP SHOWING AREA OF THIS REPORT

EXPLANATION

Holocene

Qal — Desert wash, colluvium, alluvium, and playa deposits

Qp — Playa lake deposits

WHITE MOUNTAINS, VOLCANIC HILLS, NORTH END OF FISH LAKE VALLEY, MILLER MOUNTAIN, AND CANDELARIA HILLS

- Qls — Landslide deposits
- Qoa — Older alluvium. *Chiefly gravel*
- Qm — Glacial moraine
- QTb — Basalt
- QTd — Diatomite
- QTs — Weakly lithified sandstone and conglomerate
- Tsu — Upper sedimentary unit. *Shale, siltstone, sandstone, limestone, and conglomerate*
- Tr — Rhyolite plug or flow
- Tanu — Upper nonwelded ash flow unit
- Tql — Quartz latite
- Tsl — Lower sedimentary unit. *Mainly tuffaceous sedimentary rocks. Previously referred to as the Esmeralda Formation*
- Ta — Porphyritic andesite
- Tvb — Volcanic breccia of andesitic or dacitic composition
- Taw — Welded ash flows. *Age 22.8 m.y. by K-Ar method (Robinson and others, 1968, table 1, no. 2)*
- Tanl — Lower nonwelded ash flow. *May include some airfall tuff*

SILVER PEAK AND PALMETTO MOUNTAINS

- Qls — Landslide deposits
- Qoa — Older alluvium
- QTs_4 — Sedimentary unit 4. *Weakly lithified conglomerate and tuffaceous rock*
- QTb — Basalt. *Age 4.8 m.y. (million years) by K-Ar methods (Robinson and others, 1968, table 1, no. 7)*
- Ts_3 — Sedimentary unit 3. *Tuff, shale, limestone, and conglomerate*
- Tawu — Upper welded ash flow. *Age 6.1 m.y. by K-Ar method (Robinson and others, 1968, table 1, no. 5)*
- Tpb — Porphyritic basalt
- Tpl, Ts_t — Porphyritic latite or trachyandesite. *Tpl, porphyritic latite; K-Ar age is 5.9 m.y. (Robinson and others, 1968, no. 6). Ts_t, sedimentary rocks; sandstone conglomerate, and tuff*
- Ta — Andesite. *Probably in part intrusive*
- Tafu — Rhyolitic airfall tuff. *Includes some rhyolite lava flows and possibly some nonwelded ash flows. K-Ar age 6.0 m.y. (Robinson and others, 1968, table 1, no. 4)*
- Tr — Rhyolitic flows, domes, breccias, and intrusive masses
- Ts_2, Taw_2 — Sedimentary unit 2 and welded ash flow. *Ts_2, Tuffaceous shale and sandstone. Age 11.7 m.y. by K-Ar method (Evernden and James, 1964). Taw_2, Welded ash flow*
- Tvb — Volcanic breccia. *Andesite and dacite(?) in composition*
- Ts_1 — Sedimentary unit 1
- Tawl — Lower welded ash flow. *Age 22.8 m.y. by K-Ar method (Robinson and others, 1968, table 1, no. 1)*
- Tanl — Lower nonwelded ash flow

WEEPAH HILLS, LONE MOUNTAIN, ANGEL ISLAND, AND NORTHEASTERN PART OF CLAYTON VALLEY

- Qb — Basalt
- Qoa — Older alluvium. *Chiefly gravel*
- QTb — Basalt
- Tr — Rhyolite plug or flow
- Ts, Te, Taf — Esmeralda Formation and ash-flow deposits. *Ts, Shale, siltstone, sandstone, and tuff. Te, Esmeralda Formation, shale, sandstone, and tuff. Includes some beds as young as 6.0 m.y. (Robinson and others, 1968, table 1, no. 11). Taf, ash flow tuff*
- Taw — Welded ash flow

MONTE CRISTO RANGE AND CEDAR MOUNTAINS

- Qoa — Older alluvium. *Chiefly gravel*
- QTb — Basalt
- Tg — Gilbert Andesite. *An apparent anomalously old date of 15.1 m.y. was obtained from the Gilbert Andesite (table 2, this report)*
- Tr — Rhyolite plugs, domes, and flows
- Ts — Shale, siltstone, sandstone, limestone, and tuff. *Formerly referred to as Esmeralda Formation. Correlative rocks a few miles north of Esmeralda County are 10.7 and 12.5 m.y. old by K-Ar method (Evernden and others, 1964, p. 177, 186)*
- Tql — Quartz latite and felsite. *Includes Brougher Dacite. Age 16.1 m.y. by K-Ar method (table 2, this report)*
- Trb — Rhyolite breccia. *Locally grades into welded ash flows; includes lower part of Esmeralda Formation of Ferguson and others (1953)*
- Taw — Rhyolite to quartz latite welded ash flows
- Tanf — Nonwelded ash flow

TONOPAH AREA

- Qoa — Older alluvium. *Chiefly gravel*
- QTb — Basalt. *Olivine basalt*
- Ta — Andesite. *Includes Divide Andesite*
- To — Oddie(?) Rhyolite
- Ts — Siebert Tuff. *Tuff, tuffaceous shale, and diatomitic locally; includes some sandstone and conglomerate*
- Tfb — Fraction Breccia. *Ash flows of dominantly rhyolitic composition. Correlated with rocks in Nye County which are dated at 17.1 m.y. by K-Ar method*
- Taf — Welded and nonwelded ash flows

GOLDFIELD HILLS, MONTEZUMA RANGE, CLAYTON RIDGE, AND MOUNT JACKSON RIDGE

- Qls — Landslide deposits
- Qs — Bedded clay and silt
- QTb, QTmr — Malpais Basalt and Rabbit Spring Formation. *QTb, basalt. QTmr, Malpais Basalt and Rabbit Spring Formation*
- Ttc — Thirsty Canyon Tuff. *Spearhead Member in Nye County has K-Ar age of 7.5 m.y. (Noble and others, 1964, p. 210)*
- Tar — Dark rhyolite or rhyodacite. *Dominantly agglutinate*
- Tp — Pozo Formation. *Dominantly conglomerate and subordinate sandstone, poorly consolidated*
- Tsc — Conglomerate and sandstone. *Possibly correlative with Pozo Formation*
- Tr — Rhyolite plugs, domes, and flows
- Tpl — Porphyritic latite or trachyandesite
- Ts, Tmb — Siebert Tuff and Mira Basalt. *Ts, Siebert Tuff, dominantly tuffaceous sedimentary rocks of lacustrine origin. Tmb, Mira Basalt; flows intertongues with Siebert Tuff*
- Taf, Ts, Tv — Airfall tuff and tuffaceous shale. *Taf, airfall tuff and tuff breccia of rhyolitic composition. Tss, tuffaceous shale and intertonguing airfall tuff. Tv, volcanic*
- Tc — Chispa Andesite
- Taw — Welded ash flows. *Includes Meda Rhyolite and dacite rhyolite of Ransome (1909). Age 22.1 m.y. by K-Ar method (this report, table 2)*
- Td — Dacite. *Age 20.8 to 21.0 m.y. by K-Ar method (this report, table 2)*
- Tmi — Milltown Andesite. *Age 21.5 m.y. by K-Ar method (this report, table 2)*
- Tsm — Sandstorm Formation
- Tk — Kendall Tuff and latite of Ransome (1909a)
- Tv — Vindicator Rhyolite. *Includes Morena Rhyolite of Ransome (1909a)*

SLATE RIDGE AND SOUTHERN END OF COUNTY

- QTb — Basalt
- QTg — Weakly consolidated gravel and sand
- Ttc — Thirsty Canyon Tuff. *In map area includes only Spearhead and Trail Ridge Members. Spearhead Member in Nye County has K-Ar age of 7.5 m.y. (Noble and others, 1964, p. 210)*
- Td — Dacite
- Ttm — Ammonia Tanks Member of Timber Mountain Tuff. *Welded ash flows. Ammonia Tanks Member in Nye County is 10.5 to 11.3 m.y. old by K-Ar methods (R. W. Kistler, written communication, 1965)*
- Taf — Airfall tuff and nonwelded ash flows. *May include lower part of Ammonia Tanks Member of Timber Mountain Tuff*

Holocene; Pleistocene or Holocene; Pliocene or Pleistocene; Pliocene; Miocene; Oligocene or Miocene
QUATERNARY; TERTIARY OR QUATERNARY; TERTIARY

PRE-TERTIARY SEQUENCE APPLIES TO ENTIRE COUNTY EXCEPT MILLER MOUNTAIN AND GRAPEVINE MOUNTAINS AS NOTED BELOW

UNCONFORMITY

- TJd — Dark aphanitic to medium-grained rocks of dioritic to andesitic composition
- TJa — Felsic aphanitic rhyolite and quartz porphyry dike rocks
- TJg — Coarse-grained granitic rocks. *Mainly biotite quartz monzonite but includes some granodiorite and monzonite. Also includes pegmatitic material in Mineral Ridge area*

JURASSIC TO TERTIARY

- Jd — Dunlap Formation. *Red sandstone containing lenses of conglomerate and red shale* (Lower and Middle Jurassic)

UNCONFORMITY

- Te — Excelsior Formation (Middle Triassic(?))

UNCONFORMITY(?)

- Tc — Candelaria Formation. *Shale and sandstone* (Lower Triassic)

TRIASSIC; JURASSIC

UNCONFORMITY

- Pd — Diablo Formation. *Dolomite, grit, and conglomerate*

PERMIAN

UNCONFORMITY

- Op — Palmetto Formation. *Dominantly black shale, locally contains chocolate chert, limestone, and quartzite*
- Ce — Emigrant Formation. *Mostly claystone in lower part, overlain by thin-bedded limestone with cherty layers* (Upper and Middle Cambrian)

MILLER MOUNTAIN AREA

- Csh — Siliceous hornfels
- Cm — Marble. *Possibly correlative with Mule Spring Limestone*
- Ch(?) — Harkless(?) Formation
- Cp(?) — Poleta(?) Formation. *Siliceous and calc-silicate hornfels interbedded with marble*
- Cc — Campito Formation. *Metamorphosed siltstone and quartzite*

Lower Cambrian

- Cms — Mule Spring Limestone
- Ch — Harkless Formation. *Dominantly green siltstone; locally includes strata lithologically similar to and correlative with Saline Valley Formation as defined by Nelson (1962)*
- Cp — Poleta Formation. *Mostly thick-bedded carbonate in lower part, overlain by green siltstone with limestone and quartzite interbeds*
- Ccm, Cca — Campito Formation. *Ccm, Montenegro Member; dominantly green siltstone. Cca, Andrews Mountain Member; dominantly dark-gray fine-grained quartzite*
- Cd — Deep Spring Formation. *Dominantly well-bedded limestone and dolomite; subordinate dark quartzite*
- pCr — Reed Dolomite
- pCw — Wyman Formation. *Dominantly siltstone containing thin limestone interbeds*

CAMBRIAN; PRECAMBRIAN

GRAPEVINE MOUNTAINS

- Ms — Shaly rocks. *Contains impure carbonate lenses with Mississippian fossils*

FAULT

- Op — Pogonip Group. *Thin-bedded limestone with shaly interbeds*

UNCONFORMITY(?)

- Cn — Nopah Formation. *Gray thick-bedded dolomite*

ORDOVICIAN; MISSISSIPPIAN

Contact

High-angle fault
Dashed where approximately located; dotted where concealed. Bar and ball on downthrown side. Queried where doubtful

Low-angle fault or thrust
Dotted where concealed. Sawteeth on upper plate

Anticline
Showing crestline

Syncline
Showing troughline

Note: The Esmeralda Formation is herein restricted to include only the predominantly sedimentary upper unit as mapped by Ferguson and others (1953), and to exclude the Fraction Breccia from its lower part. The Spearhead was reduced in rank to a member of the Thirsty Canyon Tuff by Noble and others (1964)

Base from U.S. Geological Survey
Mariposa, 1945; Walker Lake, 1957;
Death Valley, 1961; Tonopah and
Goldfield, 1962

Geology mapped 1960–63

GEOLOGIC MAP OF ESMERALDA COUNTY, NEVADA

By
John P. Albers and John H. Stewart

SCALE 1:250 000

5 0 5 10 15 20 MILES

5 0 5 10 15 20 KILOMETERS

CONTOUR INTERVALS 100 AND 200 FEET
DATUM IS MEAN SEA LEVEL

LIST OF MINES

1.	Mickspot	59.	Mc Nutt
2.	Royal Blue	60.	Mollini
3.	Perlex Corp.	61.	Black Rock
4.	Last Hope	62.	Silver Queen
5.	Mammoth	63.	Gold No. 1
6.	Monte Cristo	64.	Sanger
7.	Gilbert	65.	Mohawk
8.	Carrie	66.	16 to 1
9.	Eureka	67.	Nivloc
10.	Boak	68.	Western Soldier
11.	Alto Divide	69.	Mary
12.	Original Gilbert	70.	Homestake
13.	Castle Rock	71.	April
14.	Heidi	72.	Drinkwater
15.	Garibaldi & Silver Queen	73.	Last Chance
16.	Tonopah	74.	Pocatello
17.	West Tonopah	75.	Gold Hill
18.	Monarch	76.	Vanderbilt
19.	Tonopah Divide	77.	Good Hope
20.	Gold Eagle	78.	Lookout
21.	Gossan	79.	Heavy Rock
22.	Government	80.	Big 3
23.	General Thomas	81.	McNamara
24.	Valley View	82.	Paymaster
25.	Weepah	83.	Mattmueller
26.	Alum	84.	Palmetto
27.	Jet	85.	Blue Dick
28.	American	86.	Green Top
29.	Silver Zone	87.	Oasis
30.	Silver King	88.	Reed
31.	Laguna	89.	Roseamalis
32.	Merger	90.	White Eagle
33.	Combination	91.	Deuces
34.	Florence	92.	Four Aces
35.	Montezuma	93.	Sylvania
36.	Congress	94.	Cucomungo
37.	Gaillac	95.	McBoyle
38.	Sorenson Const.	96.	Mercer Bros.
39.	Black Horse	97.	Roosevelt
40.	Dicalite	98.	Six Bits
41.	AJA Quarry	99.	Seibeck
42.	Gap Strike	100.	Ohio
43.	Blanco	101.	Great Western
44.	Riek	102.	Ora Mae
45.	Buckskin	103.	Redemption
46.	Spohr	104.	Gold Mtn.
47.	Albert	105.	Stateline
48.	Morgan	106.	Snake Pit
49.	Queen	107.	Checkmate
50.	Queen Canyon	108.	Silver Moon
51.	Red Rose	109.	Huson
52.	F & L	110.	Hidden
53.	B & B	111.	Treasure
54.	Lucky	112.	Alberto
55.	Sundown	113.	Wonder
56.	Container	114.	Wylie Green
57.	Red Rock	115.	Silver Mtn.
58.	Crimson Crown		

ALPHABETICAL

AJA Quarry	41	McBoyle	95
Albert	47	McNamara	81
Alberto	112	McNutt	59
Alto Divide	11	Mercer Bros.	96
Alum	26	Merger	32
American	28	Mickspot	1
April	71	Mohawk	65
B & B	53	Mollini	60
Big 3	80	Monarch	18
Black Horse	39	Monte Cristo	6
Black Rock	61	Montezuma	35
Blanco	43	Morgan	48
Blue Dick	85	Nivloc	67
Boak	10	Oasis	87
Buckskin	45	Ohio	100
Carrie	8	Ora Mae	102
Castle Rock	13	Original Gilbert	12
Checkmate	107	Palmetto	84
Combination	33	Paymaster	82
Congress	36	Perlex Corp.	3
Container	56	Pocatello	74
Crimson Crown	58	Queen	49
Cucomungo	94	Queen Canyon	50
Deuces	91	Redemption	103
Dicalite	40	Reed	88
Drinkwater	72	Red Rock	57
Eureka	9	Red Rose	51
F & L	52	Riek	44
Florence	34	Roosevelt	97
Four Aces	92	Roseamalis	89
Gaillac	37	Royal Blue	2
Gap Strike	42	Sanger	64
Garibaldi	15	Seibeck	99
General Thomas	23	Silver King	30
Gilbert	7	Silver Moon	108
Gold Eagle	20	Silver Mtn.	115
Gold Hill	75	Silver Queen	62
Gold Mtn.	104	Silver Zone	29
Gold No. 1	63	Six Bits	98
Good Hope	77	Snake Pit	106
Gossan	21	Sorenson Const.	38
Government	22	Spohr	46
Great Western	101	Stateline	105
Green Top	86	Sundown	55
Heavy Rock	79	Sylvania	93
Heidi	14	Tonopah	16
Hidden	110	Tonopah Divide	19
Homestake	70	Treasure	111
Huson	109	Valley View	24
Jet	27	Vanderbilt	76
Laguna	31	Weepah	25
Last Chance	73	Western Soldier	68
Last Hope	4	West Tonopah	17
Lookout	78	White Eagle	90
Lucky	54	Wonder	113
Mammoth	5	Wylie Green	114
Mary	69	16 to 1	66
Mattmueller	83		

MINERAL RESOURCE MAP OF ESMERALDA COUNTY, NEVADA

SCALE 1:250 000

5 0 5 10 15 20 MILES

5 0 5 10 15 20 KILOMETERS

CONTOUR INTERVALS 100 AND 200 FEET
DATUM IS MEAN SEA LEVEL

JQS.19880517.1904

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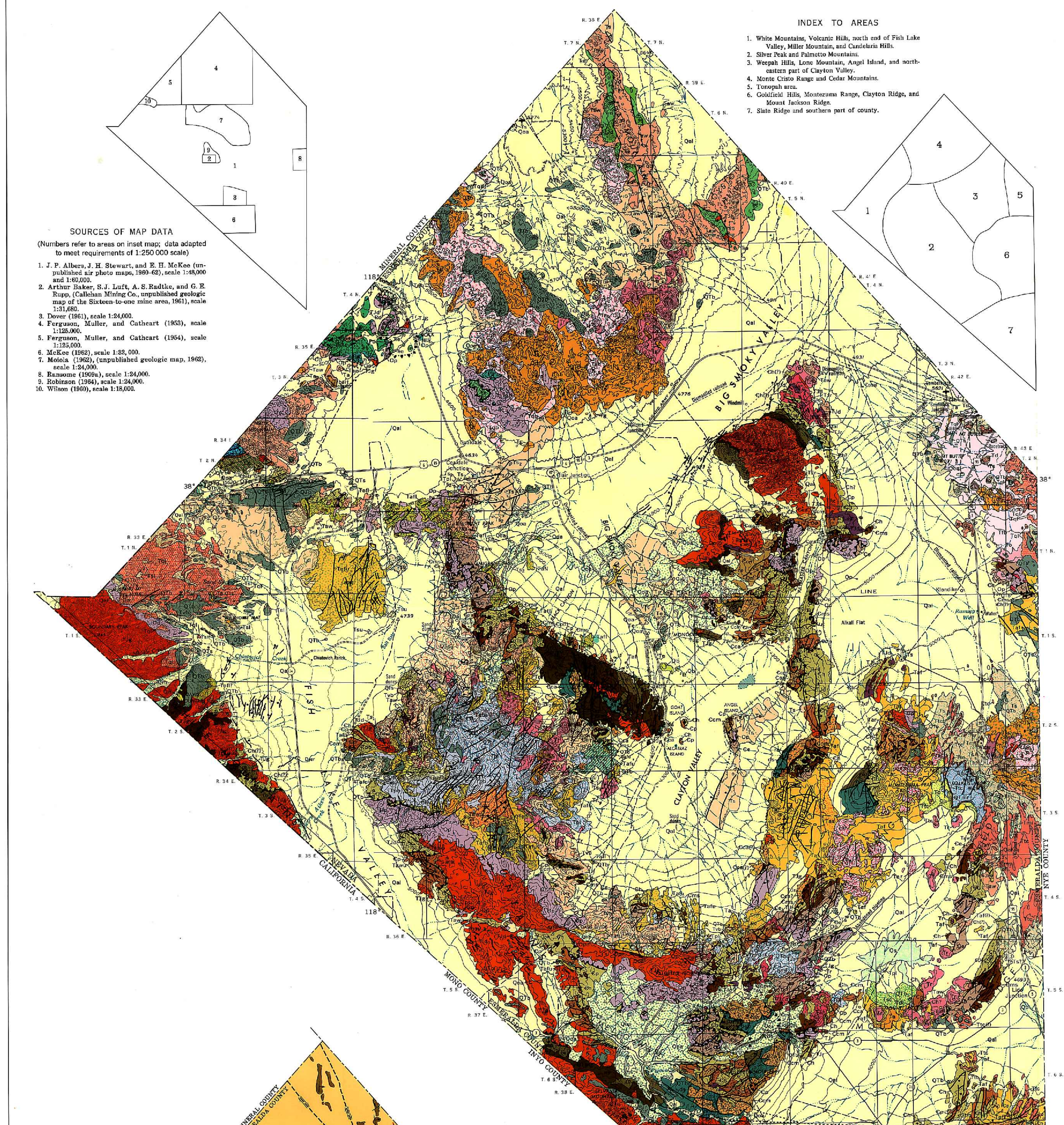


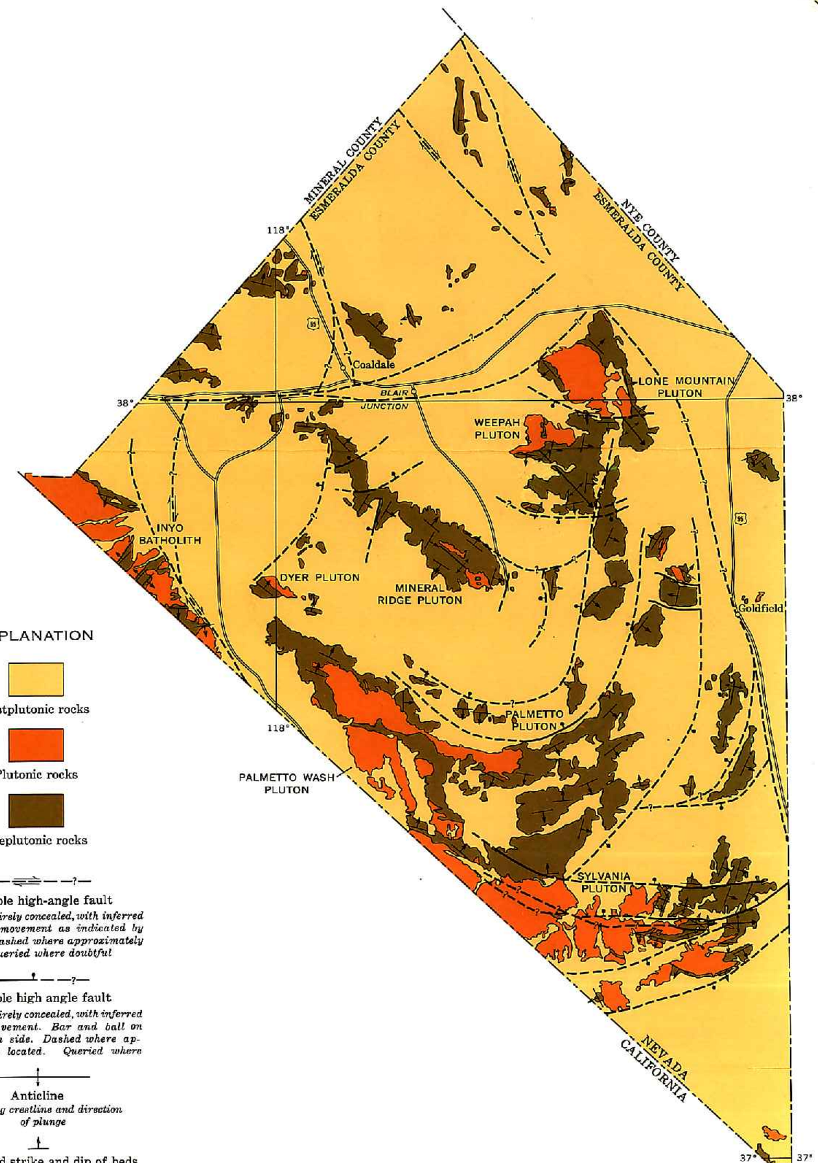
SOURCES OF MAP DATA

(Numbers refer to areas on inset map; data adapted to meet requirements of 1:250 000 scale)

1. J. P. Albers, J. H. Stewart, and E. H. McKee (unpublished air photo maps, 1960-62), scale 1:48,000 and 1:60,000.
2. Arthur Baker, S. J. Luft, A. S. Radtke, and G. E. Rupp, (Callehan Mining Co., unpublished geologic map of the Sixteen-to-one mine area, 1961), scale 1:31,680.
3. Dover (1961), scale 1:24,000.
4. Ferguson, Muller, and Cathcart (1953), scale 1:125.000.
5. Ferguson, Muller, and Cathcart (1954), scale 1:125,000.
6. McKee (1962), scale 1:32, 000.
7. Moiola (1962), (unpublished geologic map, 1962), scale 1:24,000.
8. Ransome (1909a), scale 1:24,000.
9. Robinson (1964), scale 1:24,000.
10. Wilson (1960), scale 1:18,000.

INDEX TO AREAS

1. White Mountains, Volcanic Hills, north end of Fish Lake Valley, Miller Mountain, and Candelaria Hills.
2. Silver Peak and Palmetto Mountains.
3. Weepah Hills, Lone Mountain, Angel Island, and northeastern part of Clayton Valley.
4. Monte Cristo Range and Cedar Mountains.
5. Tonopah area.
6. Goldfield Hills, Montezuma Range, Clayton Ridge, and Mount Jackson Ridge.
7. Slate Ridge and southern part of county.



EXPLANATION

Postplutonic rocks

Plutonic rocks

Preplutonic rocks

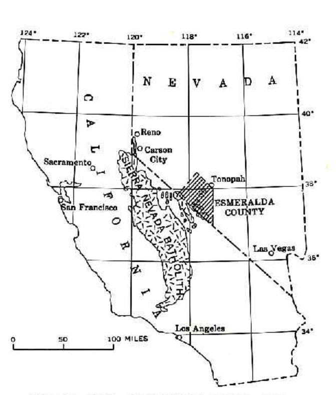
Probable high-angle fault

Probable high-angle fault

Anticline

Generalized strike and dip of beds

MAP SHOWING LOCATION OF PLUTONS AND PRINCIPAL STRUCTURAL FEATURES IN PRE-TERTIARY ROCKS (EXCEPT SOME PLUTONS OF EARLY TERTIARY AGE), ESMERALDA COUNTY



INDEX MAP SHOWING AREA OF THIS REPORT

EXPLANATION

QUATERNARY · TERTIARY OR QUATERNARY · TERTIARY

Desert wash, colluvium, alluvium, and playa deposits

Playa lake deposits

WHITE MOUNTAINS, VOLCANIC HILLS, NORTH END OF FISH LAKE VALLEY, MILLER MOUNTAIN, AND CANDELARIA HILLS: Landslide deposits; Older alluvium; Glacial moraine; Basalt; Diatomite; Weakly lithified sandstone and conglomerate; Upper sedimentary unit; Rhyolite plug or flow; Upper nonwelded ash flow unit; Quartz latite; Lower sedimentary unit; Porphyritic andesite; Volcanic breccia of andesitic or dacitic composition; Welded ash flows; Lower nonwelded ash flow

SILVER PEAK AND PALMETTO MOUNTAINS: Landslide deposits; Older alluvium; Sedimentary unit 4; Basalt; Sedimentary unit 3; Upper welded ash flow; Porphyritic basalt; Porphyritic latite or trachyandesite; Andesite; Rhyolitic airfall tuff; Rhyolitic flows, domes, breccias, and intrusive masses; Sedimentary unit 2 and welded ash flow; Volcanic breccia; Sedimentary unit 1; Lower welded ash flow; Lower nonwelded ash flow

WEEPAH HILLS, LONE MOUNTAIN, ANGEL ISLAND, AND NORTHEASTERN PART OF CLAYTON VALLEY: Basalt; Older alluvium; Basalt; Rhyolite plug or flow; Esmeralda Formation and ash-flow deposits; Welded ash flow

MONTE CRISTO RANGE AND CEDAR MOUNTAINS: Older alluvium; Basalt; Gilbert Andesite; Rhyolite plugs, domes, and flows; Shale, siltstone, sandstone, limestone, and tuff; Rhyolite breccia; Rhyolitic to quartz latitic welded ash flows; Nonwelded ash flow

TONOPAH AREA: Older alluvium; Basalt; Quartz latite and felsite; Andesite; Oddie(?) Rhyolite; Siebert Tuff; Fraction Breccia; Welded and nonwelded ash flows

GOLDFIELD HILLS, MONTEZUMA RANGE, CLAYTON RIDGE, AND MOUNT JACKSON RIDGE: Landslide deposits; Bedded clay and silt; Malpais Basalt and Rabbit Spring Formation; Thirsty Canyon Tuff; Dark rhyolite or rhyodacite; Pozo Formation; Conglomerate and sandstone; Rhyolite plugs, domes, and flows; Porphyritic latite or trachyandesite; Siebert Tuff and Mira Basalt; Airfall tuff and tuffaceous shale; Chispa Andesite; Welded ash flows; Dacite; Milltown Andesite; Sandstorm Formation; Kendall Tuff and latite of Ransome (1909a); Vindicator Rhyolite

SLATE RIDGE AND SOUTHERN END OF COUNTY: Basalt; Weakly consolidated gravel and sand; Thirsty Canyon Tuff; Dacite; Ammonia Tanks Member of Timber Mountain Tuff; Airfall tuff and nonwelded ash flows

PRE-TERTIARY SEQUENCE APPLIES TO ENTIRE COUNTY EXCEPT MILLER MOUNTAIN AND GRAPEVINE MOUNTAINS AS NOTED BELOW

JURASSIC TO TERTIARY: Dark aphanitic to medium-grained rocks of dioritic to andesitic composition; Felsic aphanitic rhyolite and quartz porphyry dike rocks; Coarse-grained granitic rocks

JURASSIC: Dunlap Formation

TRIASSIC(?) JURASSIC: Excelsior Formation

TRIASSIC: Candelaria Formation

PERMIAN: Diablo Formation

MILLER MOUNTAIN AREA: Siliceous hornfels; Marble; Harkless(?) Formation; Poleta(?) Formation; Campito Formation

ORDOVICIAN: Palmetto Formation

CAMBRIAN: Emigrant Formation; Mule Spring Limestone; Harkless Formation; Poleta Formation; Campito Formation

PRECAMBRIAN: Deep Spring Formation; Reed Dolomite; Wyman Formation

GRAPEVINE MOUNTAINS: Shaly rocks; Pogonip Group; Nopah Formation

Contact

High-angle fault

Low-angle fault or thrust

Anticline

Syncline

Note: The Esmeralda Formation is herein restricted to include only the predominantly sedimentary upper unit as mapped by Turner and others (1910); to exclude the Fraction Breccia from its lower part. The Spearhead was reduced in rank to a member of the Thirsty Canyon Tuff by Noble and others (1964)

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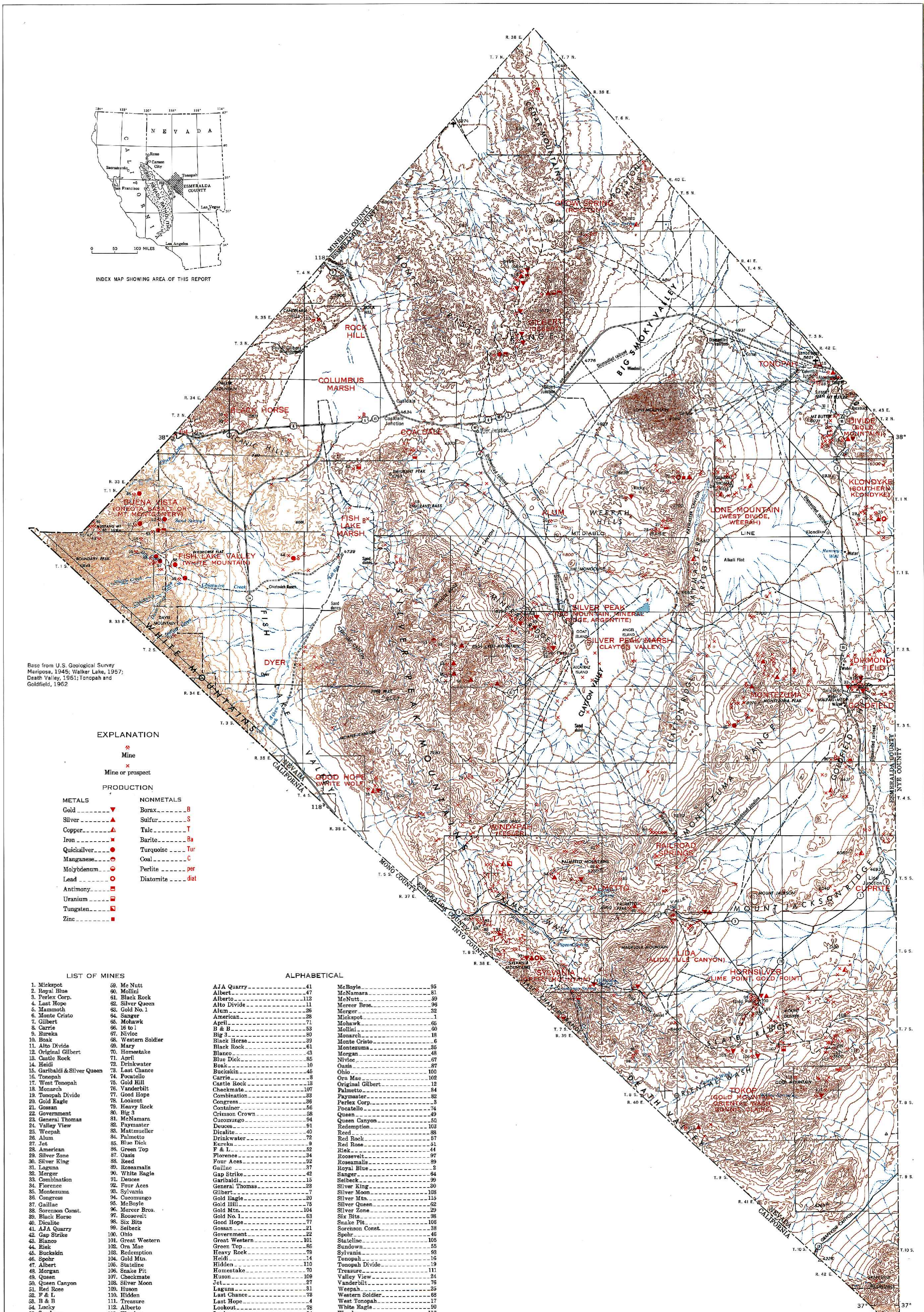
SCALE 1:250 000

CONTOUR INTERVALS 100 AND 200 FEET
DATUM IS MEAN SEA LEVEL



EXPLANATION

Mine

Mine or prospect

PRODUCTION

METALS		NONMETALS	
Gold	▼	Borax	B
Silver	▲	Sulfur	S
Copper	△	Talc	T
Iron		Barite	Ba
Quicksilver	●	Turquoise	Tur
Manganese		Coal	C
Molybdenum		Perlite	per
Lead	○	Diatomite	diat
Antimony			
Uranium			
Tungsten			
Zinc	■		

LIST OF MINES

1. Mickspot
2. Royal Blue
3. Perlex Corp.
4. Last Hope
5. Mammoth
6. Monte Cristo
7. Gilbert
8. Carrie
9. Eureka
10. Boak
11. Alto Divide
12. Original Gilbert
13. Castle Rock
14. Heidi
15. Garibaldi & Silver Queen
16. Tonopah
17. West Tonopah
18. Monarch
19. Tonopah Divide
20. Gold Eagle
21. Gossan
22. Government
23. General Thomas
24. Valley View
25. Weepah
26. Alum
27. Jet
28. American
29. Silver Zone
30. Silver King
31. Laguna
32. Merger
33. Combination
34. Florence
35. Montezuma
36. Congress
37. Gaillac
38. Sorenson Const.
39. Black Horse
40. Dicalite
41. AJA Quarry
42. Gap Strike
43. Blanco
44. Riek
45. Buckskin
46. Spohr
47. Albert
48. Morgan
49. Queen
50. Queen Canyon
51. Red Rose
52. F & L
53. B & B
54. Lucky
55. Sundown
56. Container
57. Red Rock
58. Crimson Crown
59. Mc Nutt
60. Mollini
61. Black Rock
62. Silver Queen
63. Gold No. 1
64. Sanger
65. Mohawk
66. 16 to 1
67. Nivloc
68. Western Soldier
69. Mary
70. Homestake
71. April
72. Drinkwater
73. Last Chance
74. Pocatello
75. Gold Hill
76. Vanderbilt
77. Good Hope
78. Lookout
79. Heavy Rock
80. Big 3
81. McNamara
82. Paymaster
83. Mattmueller
84. Palmetto
85. Blue Dick
86. Green Top
87. Oasis
88. Reed
89. Roseamalis
90. White Eagle
91. Deuces
92. Four Aces
93. Sylvania
94. Cucomungo
95. McBoyle
96. Mercer Bros.
97. Roosevelt
98. Six Bits
99. Seibeck
100. Ohio
101. Great Western
102. Ora Mae
103. Redemption
104. Gold Mtn.
105. Stateline
106. Snake Pit
107. Checkmate
108. Silver Moon
109. Huson
110. Hidden
111. Treasure
112. Alberto
113. Wonder
114. Wylie Green
115. Silver Mtn.

ALPHABETICAL

AJA Quarry 41
Albert 47
Alberto 112
Alto Divide 11
Alum 26
American 28
April 71
B & B 53
Big 3 80
Black Horse 39
Black Rock 61
Blanco 43
Blue Dick 85
Boak 10
Buckskin 45
Carrie 8
Castle Rock 13
Checkmate 107
Combination 33
Congress 36
Container 56
Crimson Crown 58
Cucomungo 94
Deuces 91
Dicalite 40
Drinkwater 72
Eureka 9
F & L 52
Florence 34
Four Aces 92
Gaillac 37
Gap Strike 42
Garibaldi 15
General Thomas 23
Gilbert 7
Gold Eagle 20
Gold Hill 75
Gold Mtn. 104
Gold No. 1 63
Good Hope 77
Gossan 21
Government 22
Great Western 101
Green Top 86
Heavy Rock 79
Heidi 14
Hidden 110
Homestake 70
Huson 109
Jet 27
Laguna 31
Last Chance 73
Last Hope 4
Lookout 78
Lucky 54
Mammoth 5
Mary 69
Mattmueller 83
McBoyle 95
McNamara 81
McNutt 59
Mercer Bros. 96
Merger 32
Mickspot 1
Mohawk 65
Mollini 60
Monarch 18
Monte Cristo 6
Montezuma 35
Morgan 48
Nivloc 67
Oasis 87
Ohio 100
Ora Mae 102
Original Gilbert 12
Palmetto 84
Paymaster 82
Perlex Corp. 3
Pocatello 74
Queen 49
Queen Canyon 50
Redemption 103
Reed 88
Red Rock 57
Red Rose 51
Riek 44
Roosevelt 97
Roseamalis 89
Royal Blue 2
Sanger 64
Seibeck 99
Silver King 30
Silver Moon 108
Silver Mtn. 115
Silver Queen 62
Silver Zone 29
Six Bits 98
Snake Pit 106
Sorenson Const. 38
Spohr 46
Stateline 105
Sundown 55
Sylvania 93
Tonopah 16
Tonopah Divide 19
Treasure 111
Valley View 24
Vanderbilt 76
Weepah 25
Western Soldier 68
West Tonopah 17
White Eagle 90
Wonder 113
Wylie Green 114
16 to 1 66

MINERAL RESOURCE MAP OF ESMERALDA COUNTY, NEVADA

SCALE 1:250 000

5 0 5 10 15 20 MILES

5 0 5 10 15 20 KILOMETERS

CONTOUR INTERVALS 100 AND 200 FEET
DATUM IS MEAN SEA LEVEL